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SIX-STAR SUNRISE

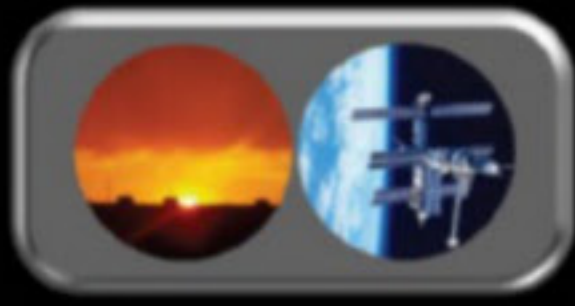
Other-world skies
with multiple Suns



10 COLOSSAL COLLISIONS

Awesome impacts that shook
the foundations of physics





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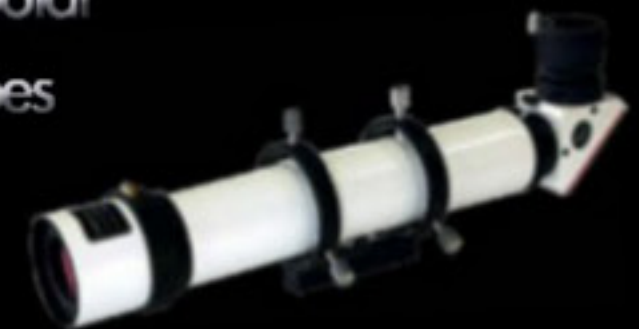
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Discover the wonders of the universe



We're all for scouring the deeper recesses of the cosmos: picking out distant nebulae, studying strange planets with the potential for life and dwelling on some of the big questions in the universe (you might want to turn to our interview on page 68 for

more on that particular topic). But there's still a great deal we can learn from the seemingly mundane objects in Earth's celestial back yard.

There's Mercury, a tiny grey planet quietly orbiting the Sun, mostly beneath the radar of our best astronomers because Mars is stealing the limelight. There it is, offering an interesting challenge to one of Einstein's fundamental laws of physics. It possibly has the answer to the question of the origins of the Solar System too, and only now is it getting the attention it deserves.

At the opposite end of the Solar System, New Horizons will reach virgin territory near the boundary of interstellar space in July next year. After a 4.8-billion-kilometre (3-billion-mile), decade-long journey from Earth, the spacecraft will finally make an historic flyby of Pluto as it moves into the Kuiper Belt. This will provide the best images and most-accurate science of the dwarf planet to date.

Don't misjudge us, we're not neglecting the rest of space this issue: we're dipping into some of our favourite topics such as supernovae, life on distant worlds and, of course, how to see some of the most fascinating and beautiful objects in the sky. It's nice to return home though, to discover what's been happening on our own doorstep recently and maybe, to see familiar sights in a totally new and unexpected light.

Ben Biggs
Editor

Crew roster

David Crookes



■ Dave set his sights on our big Mercury feature this issue. Check out this fascinating mission on page 16

Gemma Lavender



■ Gemma lives in a conveniently dark-sky spot: a great place to research her nebulae article

Giles Sparrow



■ The mysteries of deep space are a fave subject for Giles. Could there be life on alien moons?

Laura Mears



■ Laura got uncomfortably close to one of the most famous supernovae in recent history

"We will be able to better understand where we came from and how everything was formed"

Dr. Johannes Benkhoff, project scientist for Mercury's BepiColombo mission

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CONTENTS

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LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

06 From deep-sky nebulas to a classic shot from the Apollo era, we've got eye-popping images galore for you this month...



FEATURES

16 **Mission to Mercury**

This tiny planet could hold the answer to the origin of the Solar System

29 **5 Amazing Facts Meteor showers**

Incoming: a burst of curious facts and stats on shooting stars

30 **Future Tech Flexible space suits**

Introducing the skin-tight future spacesuit that could be used on Mars

32 **10 colossal cosmic collisions**

Discover the biggest, most-energetic and dynamic impacts in space

42 **Future Tech Relativity drive**

A propellant-free engine that violates a fundamental law of physics

44 **Our supernova neighbour**

What happened when a giant star unexpectedly exploded in 1987?

52 **What is the shape of space?**

The answer to this question could determine the fate of the universe

54 **Focus On Mars lander**

NASA's new lander could be the first 'flying saucer' to land on Mars

56 **Life on alien moons**

Forget exoplanets, the new search for life is on the moons that orbit them

66 **Six-star sunrise**

See what happens in a distant system with planets orbiting multiple stars

68 **Interview New Hubble telescope**

Royal Astronomical Society president tells us about Hubble's replacement

72 **Focus On Light echo**

RS Puppis displays a stunning example of this space phenomenon



16 **Mission to Mercury**

32 **10 colossal cosmic collisions**



95 WIN!

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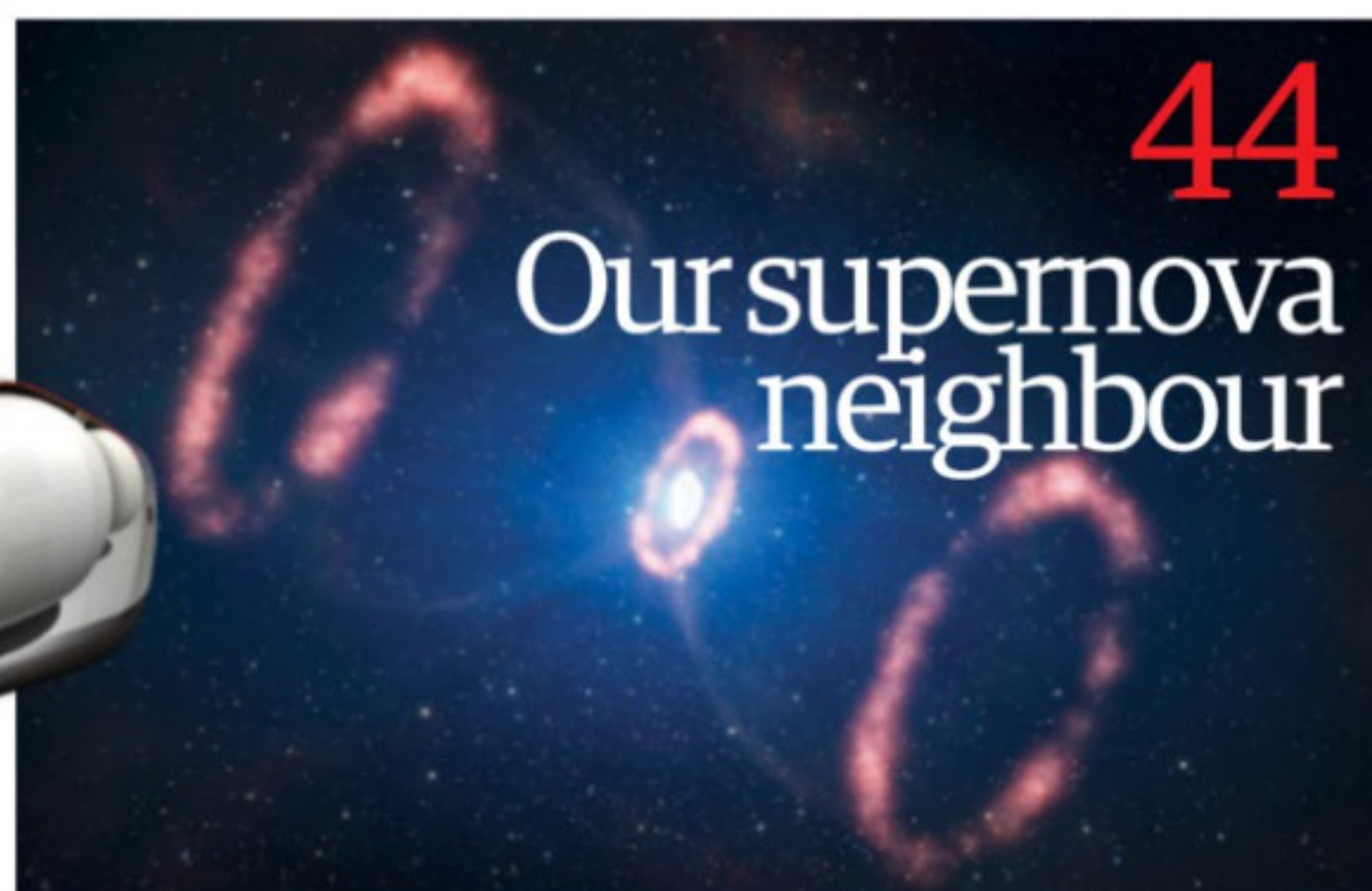


"If it answered that big question, 'are we alone in the universe?' it would be a success"

68 Martin Barstow,
Royal Astronomical Society president



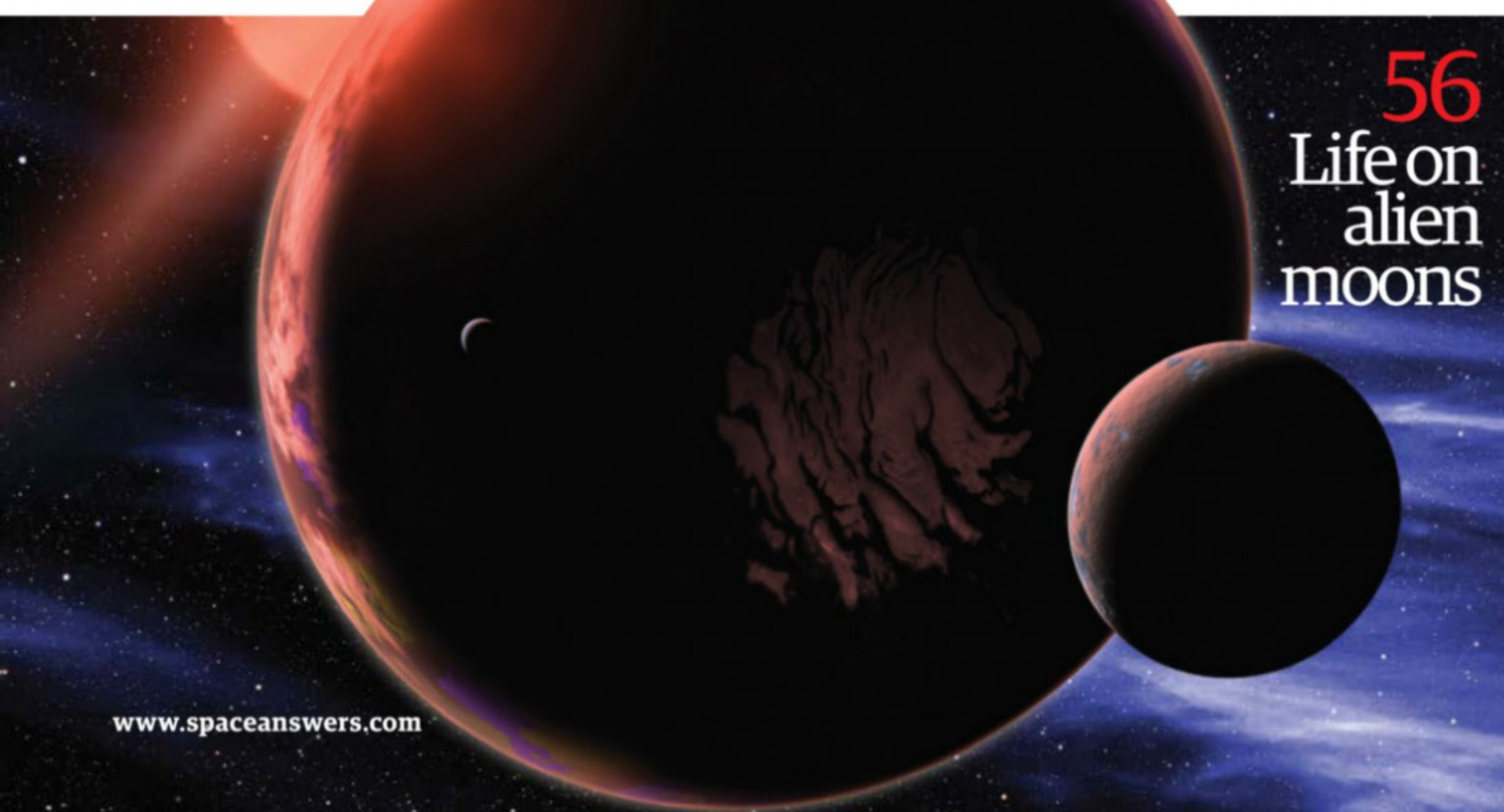
42
Relativity
drive



44
Our supernova
neighbour



66
Six-star
sunrise



56
Life on
alien
moons

Space
ANSWERS

76 Your questions
answered

Read our experts answers to
your space questions



STARGAZER

Top tips and astronomy advice
for stargazing beginners

82 How to see your
first nebula

We walk you through your first
up-close nebula viewing

88 What's in the sky?

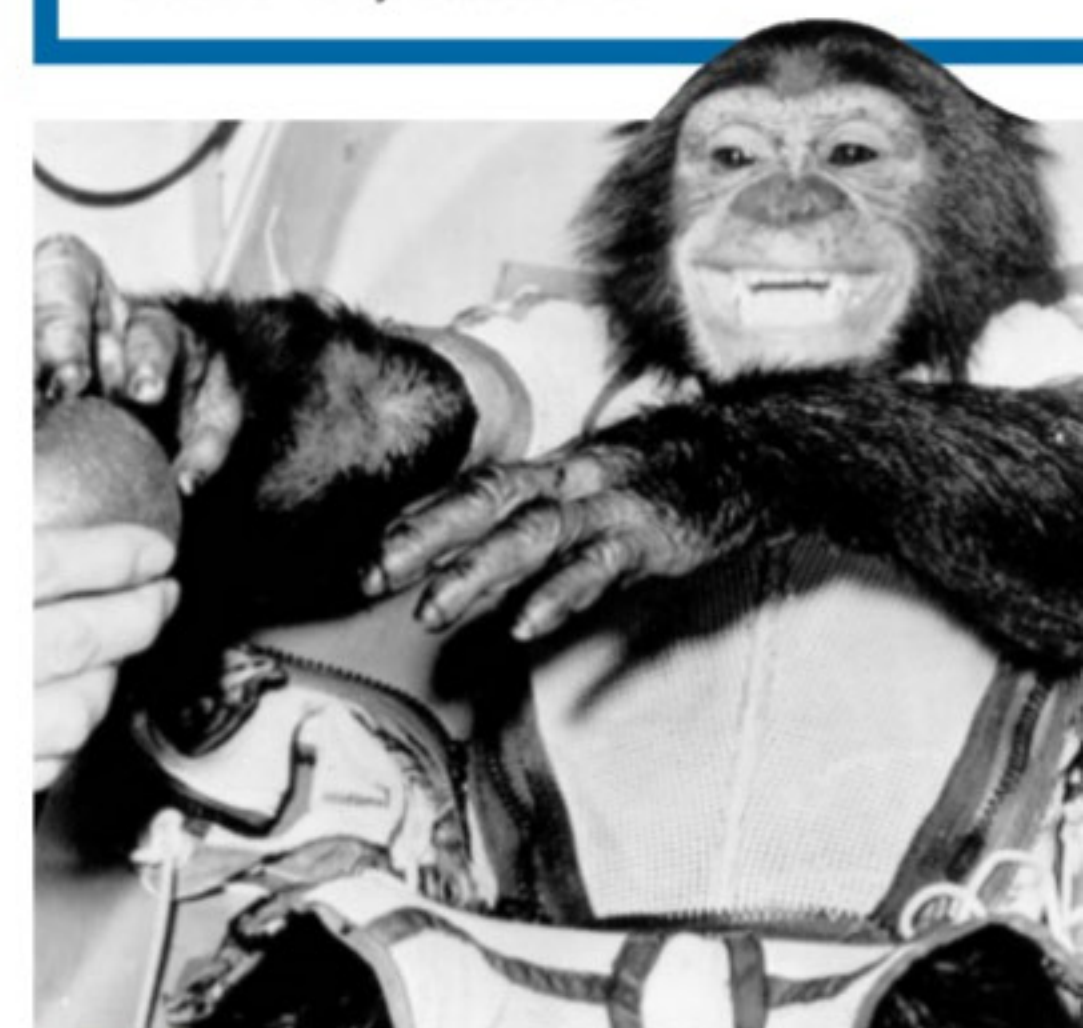
What you can see and where you
should look this month

90 Me and my
telescope

Stunning astronomy images and
stargazing tales

96 Astronomy kit
reviews

A top telescope and a choice selection
of astronomy accessories



98 Heroes
of Space

Ham, the heroic
astrochimpzee

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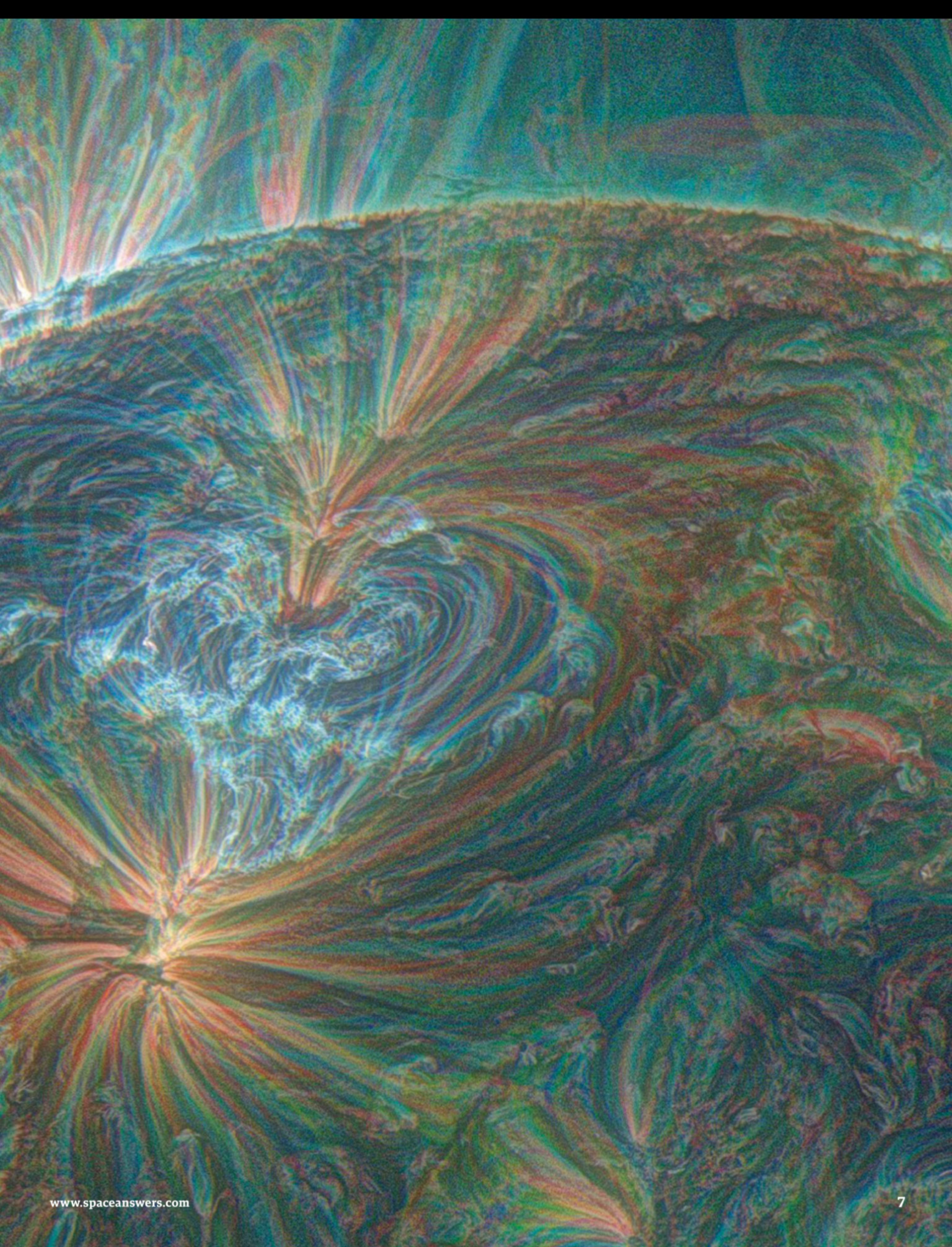
Page 74

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Three-dimensional Sun

This image was shot by several spacecraft, each taking a similar shot of the Sun from a different perspective for a three-dimensional effect. The reason for this intense scrutiny by NASA's sun-gazing SDO and STEREO spacecraft? The Sun appeared to be on the brink of a massive, but somewhat reluctant eruption, puffing out relatively tiny flares before it released a huge amount of energy and material.



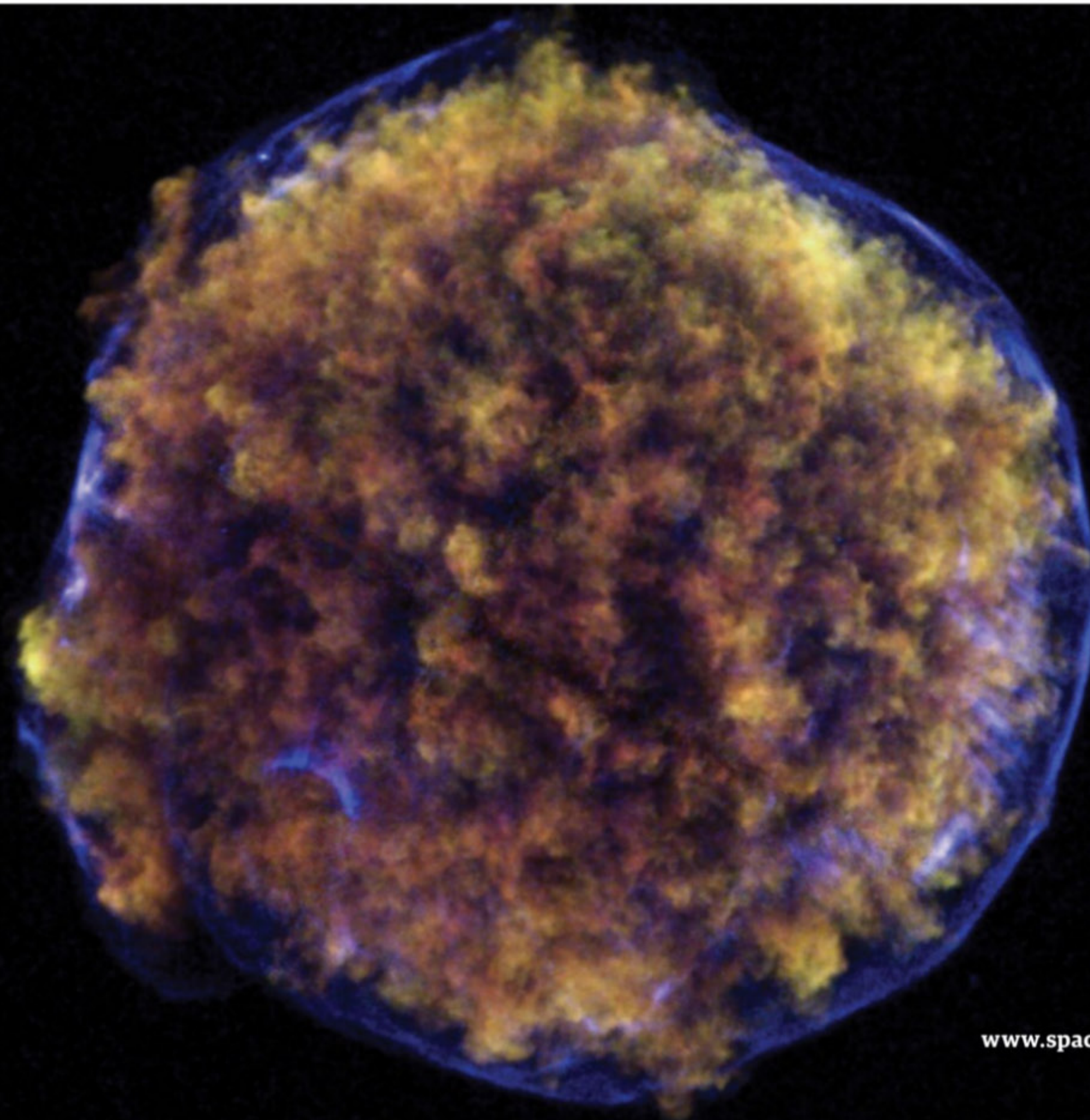
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Petri dish

What's this? A deep-sea jellyfish? Some lab-grown culture glowing in the dark? A balloon of paint exploding underwater? Actually, that one's not so far from truth. It's really a supernova discovered by Tycho Brahe in 1572. Apart from the image itself, courtesy of the Chandra X-Ray Observatory, what makes it really fascinating is the discovery that Tycho's supernova remnant was originally a binary pair. One exploded, yet despite being right next to the violent blast of its neighbour, the other has hardly been affected.



A photograph of the Aurora Australis, a southern aurora, captured from the International Space Station. The aurora appears as a vibrant, multi-colored band of light stretching across the horizon of the Earth, with hues of orange, red, and blue. The background is the deep black of space, filled with numerous stars.

The other aurora

This is an aurora, shot from the International Space Station by ESA astronaut Alexander Gerst. It's not the garden-variety Aurora Borealis though, this is the aurora that occurs around Earth's South Pole, the Aurora Australis. One of the reasons this is so seldom seen is because the zone of the Aurora Australis occurs in some of the most remote and inhospitable places of the world. Outside of Antarctica, it can sometimes be seen at high southern latitudes in parts of South America, New Zealand and Australia... as well as on the ISS, of course.

A close-up photograph of a hypervelocity bullet hole in a Nextel-Kevlar Whipple shield. The shield is a grey, woven fabric-like material. The impact has created a large, irregular hole with frayed, fibrous edges. A small, orange, egg-shaped object is visible through the hole, providing a sense of scale. The surrounding area of the shield is dark and textured.

Hypervelocity bullet hole

This material forms the Nextel-Kevlar Whipple shield of the European Space Agency's ATV space freighter: a kind of bullet-proof vest for spacecraft. Terrestrial bullets at point-blank range would bounce off it, but space can deliver an exponentially bigger punch than any Earthly projectile. This hole was made by 7.5-millimetre (0.3-inch) aluminium bullet shot at the Whipple shield by a light-gas gun at an astonishing seven kilometres a second (over 15,000 miles per hour). However, that's still slower than many extraterrestrial particles, which can travel in excess of 11 kilometres a second (over 24,000 miles per hour).

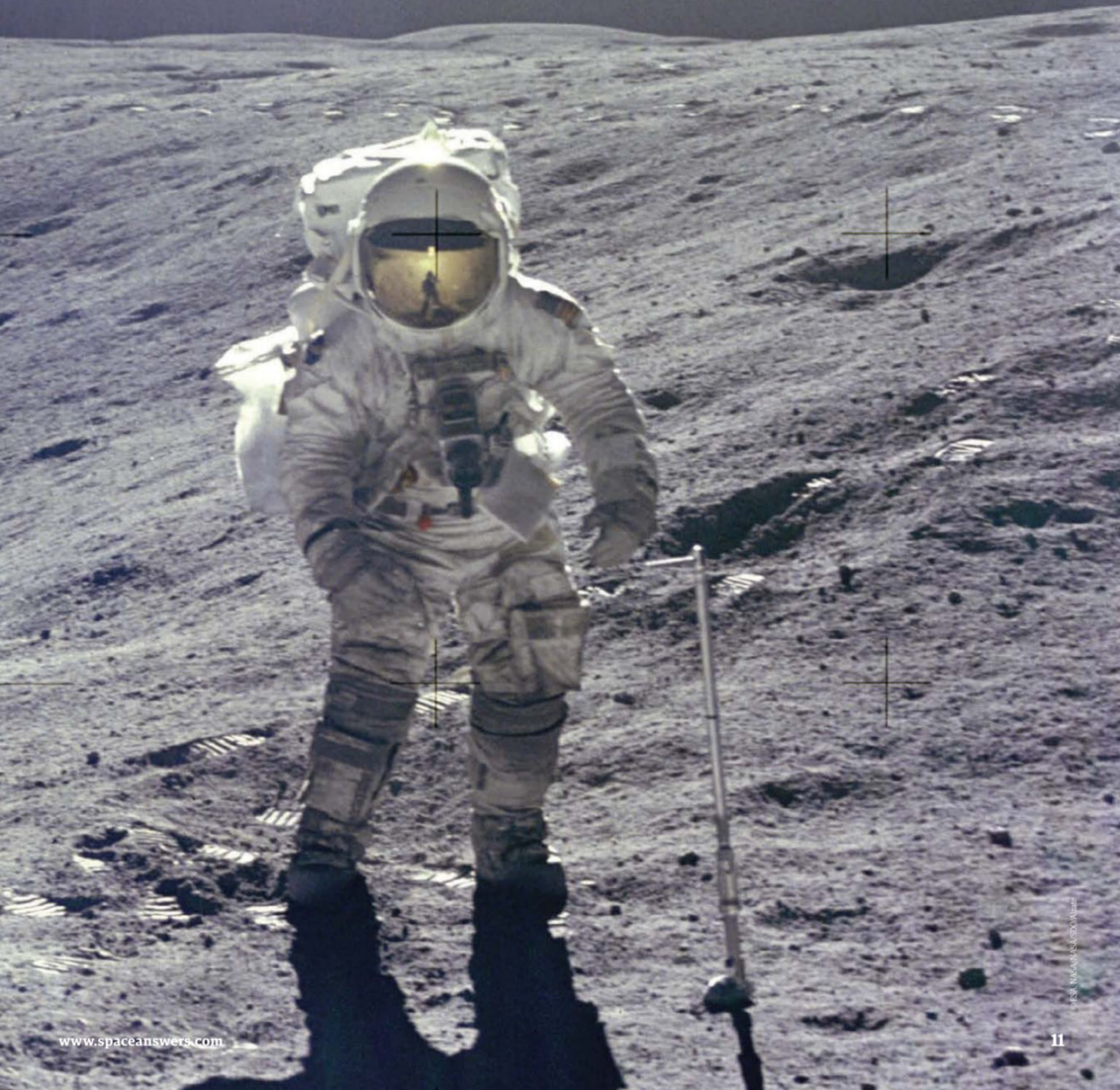
LAUNCH PAD

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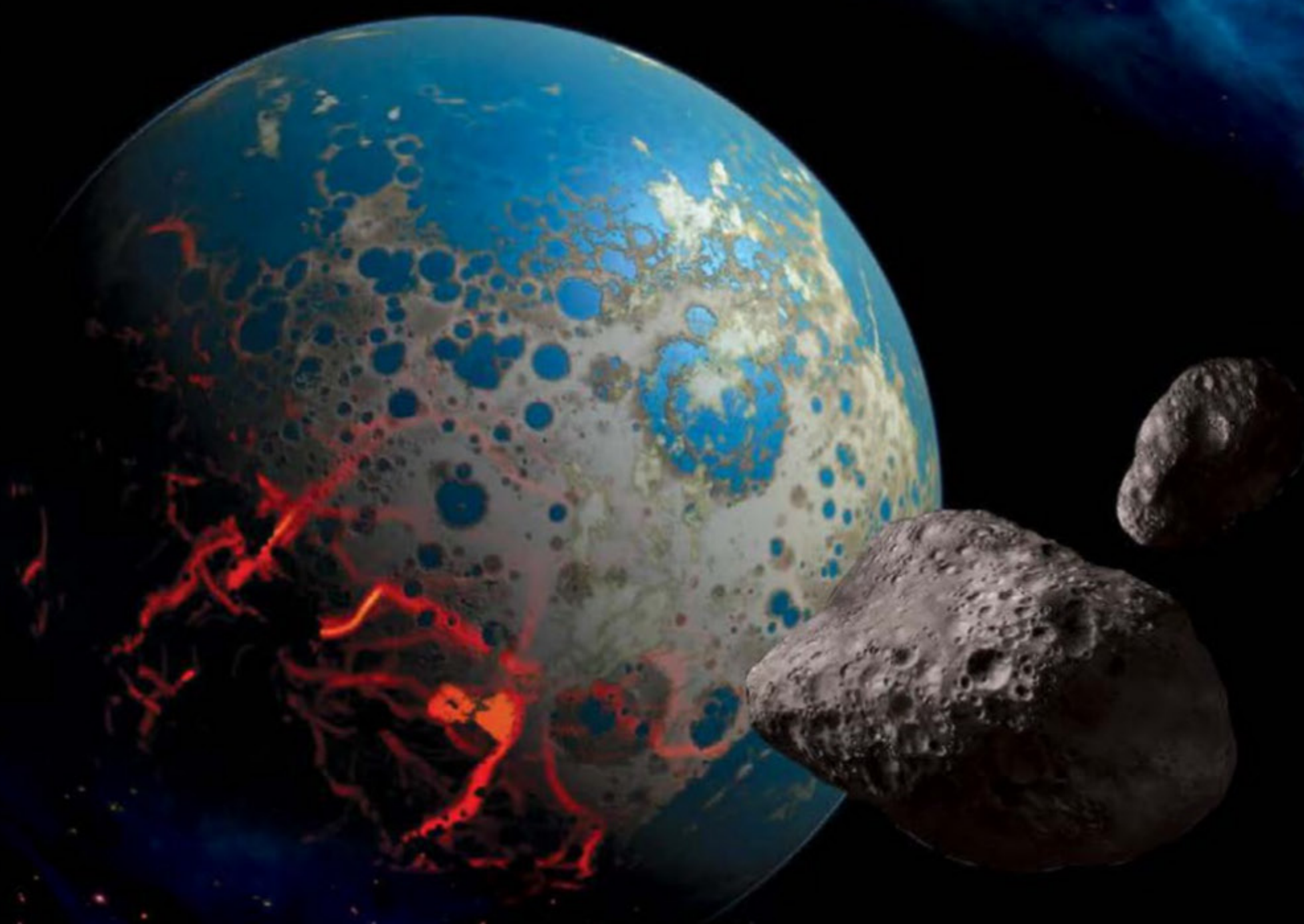
Duke on the Moon

This is Apollo 16 astronaut and Lunar Module pilot, Charles Duke, performing a Moon walk on 21 April 1972. Plum crater can be seen to the left while the Lunar Roving Vehicle is in the background, by the rim of the crater. Duke was the tenth astronaut to walk on the Moon, but remains the youngest person ever to set foot on its surface, at the age of 36. Duke will be putting in an appearance at the Starmus science festival in September 2014 on the Spanish island of Tenerife, alongside other astronauts and cosmonauts.



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The impacts that smashed into ancient Earth were so deep they extruded magma to the surface

Giant asteroids pummelled Earth

Scientists have discovered early Earth was pounded by massive space rocks that devastated its oceans and crust

A team of international researchers has published findings that reveal the incredibly violent early history of our home planet.

By creating a model of the Earth in the environment of a terrestrial aeon called the Hadean, 4 to 4.5 billion years ago, the team was able to show how the world's oldest rocks were repeatedly buried under a slew of massive impacts.

"Prior to approximately four billion years ago, no large region of Earth's surface could have survived untouched by impacts and their effects," explained senior researcher

Simone Marchi of NASA's Solar System Exploration Research Virtual Institute (or SSERVI for short).

The Hadean aeon would have coincided with an early stage in the Solar System known as the Late Heavy Bombardment Period, when the arrangement and orbits of the planets were still in flux and space rocks of giant proportions were being flung around the Solar System like cue balls on a snooker table.

Earth itself was peppered with meteorite impacts that would have had far-reaching implications for its habitability and the future of life

on Earth. Some of these impacts were apocalyptic in scale: the team estimated that a minimum of three and up to seven impactors of around 480 kilometres (300 miles) in diameter would have hit the Earth during this time. These would have boiled the early oceans and vaporised them into the atmosphere.

"No large region of Earth's surface could have survived untouched by impacts"

A smaller number of even bigger meteorites would also have hit the Earth. These were 966 kilometres (600 miles) in diameter and would have been capable of sterilising the entire planet. The only life that would have survived would have been the organisms living deep underground, or in the deepest recesses of the ocean floor. By comparison, the impactor that created the Chicxulub crater and marked the end of the dinosaurs 65 million years ago, was just ten kilometres (six miles) in diameter.

Earth's formation began with the accretion of embryonic planets (planetesimals) and, having stuck together to form a larger body over tens of millions of years, the proto-Earth was then hit by a huge object that created the Moon. Following that, huge asteroids impacted Earth, resurfacing our planet with gigantic melt sheets many times over. ●

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Curiosity approaches the Hidden Valley

NASA's Mars rover finally gets a good look at Mount Sharp, the mountain at the centre of Gale crater



Curiosity's main science target, Mount Sharp, looms ahead

"It's thought these lower layers could have originally formed part of a huge lake bed"

Two years after the Mars Science Laboratory (MSL) mission landed in Gale crater on Mars, its Curiosity rover has finally made it to the foothills of the huge mountain at its centre. Mount Sharp (known as Aeolis Mons) has a peak 5.5 kilometres (3.4 miles) high, but it's the lower slopes that interests the science team.

The rover's current location is a sandy dip in the terrain dubbed the Hidden Valley, which Curiosity must traverse to reach its next goal, around 500 metres (1,640 feet) away. Here, an outcrop called the Pahrump Hills marks the beginning of a major change in the terrain, from impact basin to mountain. The Pahrump Hills are considered an appetiser of sorts for the long-term science destinations of Mount Sharp's lower slopes, three kilometres (two miles) from Curiosity's current location.

Curiosity will be able to sample the bedrock of the mountain, which is in sediment-like layers and may have been laid down over 2 billion years.

The rover landed on 6 August 2012 with the primary goal of assessing Gale crater to see whether it has ever been a suitable habitat for microbial life. It landed around ten kilometres (six miles) away from the base of Mount Sharp. However, because of its low top speed (around four centimetres or 1.5 inches per second), its science objectives and detours to avoid rough terrain, it has taken this long to journey from the Bradbury Landing site to its position. ●

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From the makers of How It Works: a fun and accessible magazine for young readers

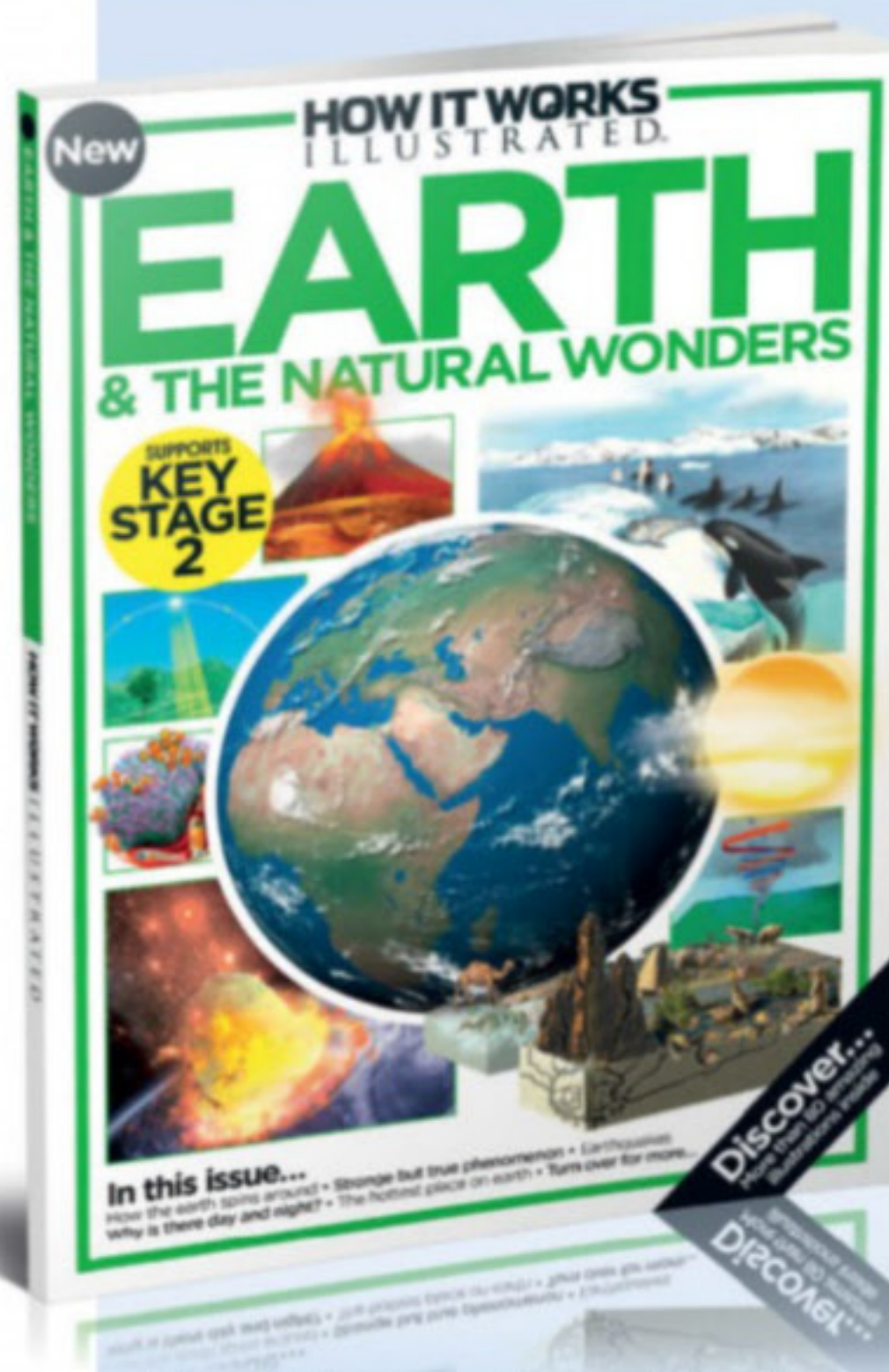
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Explore and discover the world we live in and beyond with issue two of **How It Works Illustrated**, the new science magazine for younger readers, on sale from newsagents and supermarkets from 28 August. ●



The exciting second issue of **How It Works Illustrated** presents a guide to Earth's natural wonders



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Stardust mystery clearer

Astronomers have tracked the creation of stardust during the aftermath of supernova SN2010jl. Its creation was previously a complete mystery, but now it's thought it formed in material ejected just prior to the blast.

Fermi finds new gamma-ray source

NASA's Fermi gamma-ray Space Telescope has confirmed that stellar eruptions known as novae usually create gamma rays. Fermi has detected this extreme form of energy from novae in no less than four cases now.

Ten years in space

The Mercury orbiter Messenger (MErcury Surface, Space ENvironment, GEochemistry and Ranging) celebrated a big milestone recently: ten years in space, 7.9 billion kilometres (4.9 billion miles) travelled and 15 orbits of the Sun completed.

Most-distant galactic lens discovered

The Hubble Space Telescope has discovered the most-distant massive galaxy that acts as a cosmic magnifying glass. The huge gravitational lens has magnified the light from a galaxy behind it, 10.7 billion light years from the Earth.

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The evolution of the planet, from 2,800 to 150 degrees Celsius (5,027 to 302 degrees Fahrenheit), left to right

Cool planet was once a hot as a star

An international group of astronomers has discovered a relatively cool planet that they suspect could once have been a hot star. The planet (WISE J0304-2705) has a temperature between that of the Earth and Venus, of around 100 to 150 degrees Celsius (212 to 302 degrees Fahrenheit).

Found in the Furnace constellation in the Southern Hemisphere, the planet is a ball of gas like Jupiter or Saturn, but shows evidence of a possible ancient origin that suggests there was massive temperature change at some point. It might even have spent its early days as hot as a small star.

"Our measurements suggest that this Y dwarf may have a composition and/or age characteristic of one of the galaxy's older members," said Professor David Pinfield of the University of Hertfordshire, who led the team. "Its temperature evolution could have been rather extreme - despite starting out at thousands of degrees, this exotic object is now barely hot enough to boil a kettle."

The planet would have started with a temperature of 2,800 degrees Celsius (5,072 degrees Fahrenheit) that lasted for 20 million years. It cooled to 1,500 degrees Celsius (2,732 degrees Fahrenheit) after 100 million years, then 1,000 degrees Celsius (1,832 degrees Fahrenheit) after a billion years. Several billion years passed before the team spotted the planet at its current temperature today. ■

Huge eruption recorded on Io

Observatory spots the Solar System's biggest eruption on Jupiter's moon

Astronomers at the University of California, Berkeley have captured an image of the biggest ever volcanic eruption detected in the Solar System.

The image itself was obtained by the Gemini North Telescope (situated in Hawaii) on 29 August 2013 and is being described as the grande finale in a series of large volcanic outbursts that rocked the surface of the moon for several weeks.

The giant eruption was over ten thousand times more powerful than Iceland's Eyjafjallajökull, which caused air traffic chaos when it popped in 2010.

Io's giant volcano spouted several cubic kilometres of lava and had a power of around 20 trillion watts - more than the total power consumption of the world. The moon is subject to the enormous

gravitational forces of its parent Jupiter, which puts the entire moon under intense stress and creates extreme volcanism at its surface.

Combined with the low gravity of the moon, the resulting eruptions from Io's enormous volcanoes can emit huge amounts of energy and spray to heights many times that of any terrestrial volcano. ■



The Gemini North Telescope image of Io shows the huge eruption on the upper-right of the moon

Win a ticket to Starmus 2014 festival

Enter the Ask Hawking competition for a chance to win

Organisers of the Starmus Science Festival 2014 have announced an epic prize for one lucky winner in the Ask Hawking competition. Open to the general public, entrants can put their questions to one of the leading lights of science, Stephen Hawking.

Four winners will be allowed to walk onto the stage at the Starmus 2014 Science Festival in the Canary Islands (which runs from 22-27 September) and ask Steven Hawking



Stephen Hawking is the keynote speaker at Starmus 2014, 22-27 September, Tenerife

their question. One lucky winner of the Ask Hawking competition will even receive a free ticket to Starmus 2014 - worth €300 (£240 / \$400)!

To enter, simply post your question on the Ask Hawking Facebook page (StarmusFestival) or email Starmus directly with your question at hawking@starmus.com.

Closing date for the competition is 29 August and the jury will announce the winners on 1 September. The four winners will put their question personally to Stephen Hawking, giving

them the opportunity to go on stage and experience a unique moment with the renowned physicist.

The non-professional public can enter the competition through their attendee registration on the festival website (www.starmus.com) or, for those who are not attending, through the Starmus Facebook page.

Starmus is the stand-out encounter in the field of popular science, in an original format where music and the stars come together on the beautiful island of Tenerife. ■

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MISSION TO MERCURY

Small, hot and so very far away – just what are astronomers hoping to learn from the multi-million-pound mission to Mercury and what secrets of the Solar System could it uncover?

Written by David Crookes

It may be the smallest of the Solar System's four terrestrial planets, but around seven times a year, when it's at its greatest elongation, Mercury is clearly visible to the naked eye. To a casual observer, Mercury looks like our Moon, but it has the potential to unlock many secrets not only about itself, but Earth and the entire Solar System.

For that reason, scientists are working on a mission to Mercury called BepiColombo. It will be unmanned, which is sensible given that Mercury is the closest planet to the scorching ball that is the Sun, giving the planet temperatures as high as 430 degrees Celsius (806 degrees Fahrenheit). There is no chance of being able to place an astronaut on its surface, but scientists still have a burning desire to study Mercury in greater detail. "It's an important piece of the puzzle that will enable us to better understand the evolutionary history of our Solar System," says the mission's project scientist Dr Johannes Benkhoff. "We'll be able to better understand where we came from and how everything was formed."

BepiColombo has been in the planning as far back as the 1990s. It's a joint mission of the European

Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA). It's named after Giuseppe Colombo, a scientist, mathematician and engineer at the University of Padua in Italy who died in 1984.

The scientific objectives are to study the interior structure, geology, composition and form of Mercury. The mission will help experts better understand the dynamics of Mercury's magnetic field and atmosphere. With a launch date fixed for July 2016 and its arrival in Mercury's orbit set for 2024, it won't be too long before scientists are able to test their theories and witness some breakthrough discoveries.

"There's no other way of doing this," says Dr Benkhoff. "To properly study Mercury from Earth, you have to look in the direction of the Sun. We can't use expensive telescopes like Hubble to do this because there is a risk... you could destroy some instrumentation. We need this space mission in order to get more details and to better explore Mercury."

This tiny planet is only a little bigger than our Moon – you could fit 18 Mercurys inside the volume of Earth! Astronomers believe its exterior is a crust of silicate rock, but if you could slice into it, you

would see that it has a massive iron core some 4,150 kilometres (2,580 miles) in diameter. Under the crust is rocky silicate mantle and two-thirds of the planet is said to be metallic and a third silicate. The thin atmosphere (exosphere) of oxygen, sodium, hydrogen and potassium doesn't cause objects to burn up, so they smash into the planet's surface.

We know a fair amount about Mercury because BepiColombo will not be mankind's first mission to the planet. In 1974 and 1975, NASA's Mariner 10 flew past Mercury three times and delivered many close-up images. This was useful since it was the first time astronomers had seen the planet that way, but the low-res images didn't tell them enough. After Mariner 10, European scientists realised there was still much to learn and began to talk about their own mission. As time went on, the Americans also began to think about returning to Mercury. Of the two, the US won the race, with NASA's Messenger spacecraft performing three flybys of Mercury. In March 2011, Messenger entered Mercury's orbit and began to map the surface of the planet, sending back rich data. This has since proved to be very useful.

Mission to Mercury

Although NASA's headstart could have been annoying for those working on BepiColombo, it has given the Europeans something else to work from. "The Americans had similar plans at around the same time," says Dr Benkhoff. "In a way, they overturned us with Messenger but on the other hand, because we have close interaction with NASA and other space agencies, we are able to benefit from their experience. We can talk about challenging things like multi-layer insulation or solar areas."

BepiColombo remains vitally important for many reasons. It seeks to investigate the origin and evolution of a planet that is close to a parent star, which will give insight to similarly placed planets in other galaxies. The mission also wants to time Mercury's orbit around the Sun to test Einstein's theory of general relativity. BepiColombo will also study Mercury's interior and investigate its origin.

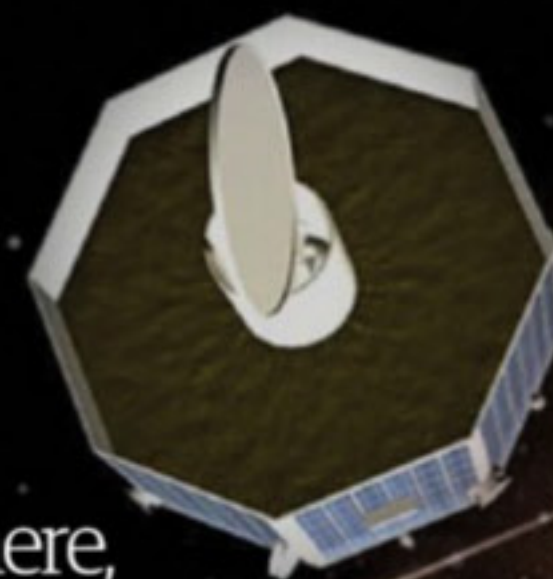
BepiColombo also wants to know if Mercury is tectonically active today, as well as test whether its density really is higher than other terrestrial planets. Also, models show that the planet should predominantly be made up of iron, but spectroscopic observations (the different wavelengths radiated off the planet) currently reveal no iron. Mercury has been so under-explored that we can't be totally sure of what we think we know using current data. Yes, we think we know that Mercury has a large core, but only by testing the planet's shape, rotation, gravity field and axis tilt will scientists be entirely certain.

Flying a spacecraft to Mercury and finding out the right answers is no easy task. More energy is needed to go to Mercury than to the dwarf planet Pluto, due to the direction of the journey. The strong gravity of the Sun means the spacecraft has to be carefully steered so that it doesn't fall into the star. The spacecraft must also decelerate rather than accelerate. "The problem is to get the spacecraft into an orbit around the planet," says Dr Benkhoff. "So you decelerate into the direction of the Sun, bring it into an orbit and then catch up with the speed of Mercury because it rotates quite fast around the Sun."

As if that weren't problematic enough, the BepiColombo mission involves two orbiters - one created by ESA and the other by JAXA. The Japanese are contributing the Mercury Magnetospheric Orbiter (MMO) and ESA is building the Mercury Planetary Orbiter (MPO). Both will study Mercury from different orbits. "Our spacecraft is focused more on the planet itself: its interior and its surface," says Dr Benkhoff. "The Japanese spacecraft will be studying Mercury's environment and the magnetosphere and exosphere around the planet. If you have two spacecraft at the same time, you can measure some gradients and separate the magnetic fields..."

The spacecraft

To analyse Mercury and its atmosphere, both the Mercury Planetary Orbiter and Mercury Magnetospheric Orbiter need to pack an array of high-tech instruments



High-gain antenna

This antenna has a focused and narrow radiowave beam width that is used to communicate data.

Radiator

Because of the incredible heat felt by the MPO, it needs a radiator to enable heat to dissipate.

Magnetometer

The dual fluxgate magnetometer on the MPO will measure direct current and low-frequency perturbations of the magnetic field.

Instruments

The MPO includes an X-ray spectrometer, laser altimeter, optical cameras and an infrared spectrometer.

Star sensors

These will determine the position of the MPO when it's in orbit.

Medium-gain antenna

The MGA is a bi-reflector type antenna that proves medium amplification of radio frequency signals. It's located on the lower surface of the MPO.

Solar Cell

A solar panel juts out of the body of the MPO. It's relatively small because the probe will fly close to the Sun.

Why is Venus hotter than Mercury?

On the surface it seems odd that Venus, which is the second-closest planet from the Sun, is actually hotter than Mercury, which is closest. Mercury can be as hot as 430 degrees Celsius (806 Fahrenheit), but temperatures on Venus will reach an average of 464 degrees Celsius (867 Fahrenheit).

Venus' atmosphere is the reason for this bizarre difference. It's almost completely made of carbon dioxide, which traps the heat and ensures it doesn't cool down. Venus has the thickest atmosphere in the Solar System, which is why it's the hottest of all the planets. No heat wave on Earth even comes close.



Mission interview



Jan Van Casteren, project manager of BepiColombo, European Space Agency

Why is it important to investigate Mercury?

Mercury is a very difficult planet to observe, certainly from the Earth - you have very few opportunities and a lot of stray light from the Sun. The best way is to actually go there.

What do you think will come out of the BepiColombo mission?

We need to look closely at the density of the planet. Mercury has a very high density and this goes back to how it was formed in comparison with the other planets. Mercury has a magnetic field and that was a big surprise. Why is it still not understood?

How much focus is on the evolution of planets in general?

There are still major and fundamental questions about the evolution of planets and their origins - how they came into existence and evolved. If we look at the Earth-like planets - Mercury, Venus Mars - they are all very different. Only Earth was able to produce life, but why? And why are they so different? Why does life exist?

Is exploration of Mercury needed to answer these questions?

You have to investigate all of the planets for a better understanding and Mercury was the missing link.

What difficulties have you come across?

The main technical challenges have been due to the very high temperatures the spacecraft will have to experience.

How will the sections of the spacecraft cope with the high temperatures?

Everything that is on the outside of the spacecraft has to be able to withstand the high temperature, so that means the insulation and the blankets - the multi-layer insulation - as well as the solar array, the antenna and the antenna mechanism must be looked at. They are all out in the open and subject to the radiation of the Sun.

High-gain antenna

Scientists will be able to communicate with the MMO via the high-gain antenna that sits on top and the medium-gain antenna at the bottom.

Wire antenna

There are four wire antennas protruding from the MMO's body. They are used to measure the electric field and the radio waves.

First mast

There are two extendible, five-metre (16.4-foot)-long masts for magnetic field measurements. An MGF-0 sensor sits at the tip of one mast with an MGF-1 sensor located around halfway along. These will provide detailed descriptions of the magnetosphere, as well as the relation and interaction with solar wind and the magnetic field.

Second mast

This other mast has search-coil magnetometers. By putting these magnetometer* sensors on the masts, they can be separated from the spacecraft body and so work more effectively.

Particle detector

The particle detector will pick up any airborne particles for analysis.

Solar cell

The eight side panels of the MMO are fitted with solar cells that have an aggregate power-generation of ~350W.

OSR

Optical Solar Reflectors cover the side panels. They have high dissipation efficiency, helping to reduce the extreme temperatures the MMO will otherwise suffer.

Mercury dissected

Wish you were here? We look at the various features of Mercury, a planet with little atmosphere but so much potential for scientific discovery and with lots of hidden extras

Rocky silicate mantle

Rocky silicate mantle is believed to surround the iron core.

One layer

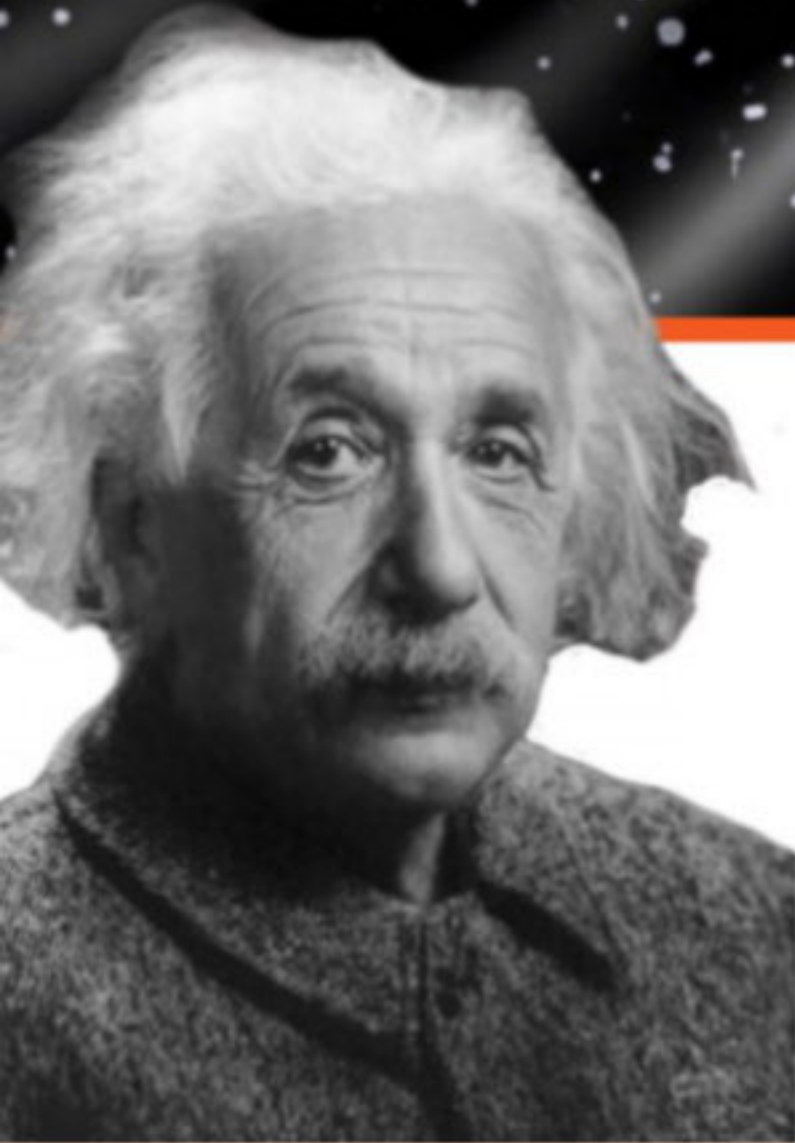
Mercury has one rocky layer, as opposed to the several plates of crust on Earth.

Hemispheres

BepiColombo will give astronomers full visibility of the global planet surface.

Density

Normal terrestrial planets have a relationship between their size and density, but Mercury is much more dense for its size.



Testing Einstein

Albert Einstein's general theory of relativity says the force of gravity arises from the curvature of space and time. It was put forward as a theory because, at the point where Mercury was closest to the Sun, the planet was flying in the face of Isaac Newton's theory of gravity.

Mercury was found to orbit differently to how Newton predicted and was moving at a faster rate. Einstein explained it by saying it was following the path predicted by the curvature of space-time. BepiColombo will measure Mercury's motion more accurately and test the theory fully.

Cooling down

Mercury's iron core has been cooling over the past four billion years and this has a dramatic affect on the planet's size. Already the innermost and smallest planet in the Solar System, the cooling has caused it to shrink by around 14 kilometres (nine miles) in diameter. This has caused fracturing of the surface crust of Mercury, creating the rugged topography.

Caloris Basin

When an asteroid crashed into Mercury it left this large impact crater. Although it was discovered in 1974, NASA's Messenger mission revealed it to be much bigger than originally believed. The crater is some 1,500 kilometres (932 miles) wide and is surrounded by mountains that are two kilometres (1.2 miles) high at their peak.

Ancient volcanos

NASA's MESSENGER mission has picked up on ancient volcanos on Mercury's surface. It was thought Mercury lacked volatile compounds, but it would seem volcanos erupted for much of the planet's history. One is a staggering 97 kilometres (60 miles) in diameter.

Magnetic field

Of the Solar System's four terrestrial planets, only Earth and Mercury have a magnetic field. Mercury's dynamo magnetic field is far weaker than Earth's and is just one per cent as strong.

Did you know?

Mercury follows a strange elliptical orbit. It can be as close as 46 million km (29 million miles) and as far as 70 million km (44 million miles) when it swings out.

Since the MMO is set to orbit Mercury for at least one Earth year, there will be

many opportunities for the Japanese spacecraft to sample the magnetosphere at a high altitude. The magnetosphere is highly influenced by the Sun over Mercury's seasons, so it will be tested all year round. The MPO, meanwhile, will be able to sample the magnetosphere at lower altitudes. With the MPO carrying out many other tasks, the two spacecraft will build an overall picture of Mercury. We'll be able to see the results of this data gathering, too. The BepiColombo mission enables high-resolution imagery of the complete planet to be captured, giving the mission full visibility of the global planet surface. By contrast, Messenger concentrated only on one specific hemisphere of the planet.

Both orbiters will be carried by the Mercury Composite Spacecraft (MCS), which will include the MMO Sunshield and Interface Structure (MOSIF) to provide thermal protection and the necessary mechanical and electrical interfaces for the Japanese craft. The spacecraft will also include the Mercury Transfer Module (MTM), providing solar-electric propulsion. Both are being built by ESA. There would have been a lander too - ESA wanted to land on Mercury - but the cost was too high, so these plans to land on Mercury were eventually scrapped.

"[The lander] was part of the initial idea for BepiColombo. For cost reasons it was dropped and, of course, that was disappointing," says Dr Benkhoff. "For sure, that is one of the next steps to come: we do plan to have a mission with a lander in the future."

Still, with ESA and JAXA working side-by-side, the mission goals will be better fulfilled. "If you are interested in Mercury itself, your goal would be to get the remote sensing instruments as close to the

Mission interview



Nicolas Thomas, professor of experimental physics at the University of Bern, Switzerland

You are the co-principal investigator working on the BepiColombo Laser Altimeter. How does it measure the topographic relief of Mercury?

BELA fires a laser at the surface of Mercury and measures the flight time between the firing and the reception of light reflected from the surface

How important is this technology for geophysics and geology?

By measuring the topography of the surface, we can measure the shape of Mercury and determine any offset between the centre of mass and centre of the figure. In this way we can see if Mercury has internal mass displacements. We can also measure simple things very accurately such as the height of scarps, depths of craters and so on, which enables us to determine if craters have been filled with material over Mercury's history or how strong the tectonic activity on Mercury was necessary to be to produce huge uplifts of material.

What are you hoping will be shown by the scientific studies conducted during the BepiColombo mission?

We believe that water has migrated to the poles and formed water ice deposits in [sheltered] crater bottoms. The camera can't see this stuff because there is no sunlight, but the laser brings its own light source. We should see a very strong return pulse from the laser if the deposit is bright and a very weak one if the ice has sublimed and left a so-called lag deposit. We can then try to estimate how much water has been brought to Mercury by comets, for example.

planet as possible for a thorough investigation," Dr Benkhoff continues. "But if you are interested in the environment, it's better to also have spacecraft that go a little bit further, where you see the interaction of the solar wind with Mercury's magnetic field."

The two orbiters will generate different results from that of NASA's mission. Messenger is able to get great, high-res images to the north of Mercury but it's too far away from the south, leading to poorer coverage there. BepiColombo's two spacecraft will go some way to redressing this as well as expanding on the work being carried out by Messenger. One thing intriguing astronomers, for instance, are the hollows that were found by Messenger in recent years. These are structures on the surface that look like volatile activity has recently gone through the ground, similar to salt lakes on Earth.

What BepiColombo hopes to find

What Mercury is made of

Just as some believed the Moon was made of cheese, you never quite know what you're dealing with until you get there. Any understanding of the form and geology of a planet is useful. BepiColombo also wants to get under Mercury's skin and discover its interior structure.

Mercury's origins

How did it actually form and how has it evolved? Mercury is close to the Sun and there are many other planets in close proximity to their parent stars in other galaxies. Greater insights into Mercury opens up greater understanding of the other planets.

Better insight into the planet's magnetosphere

Mercury has a magnetic field but it has always been a surprise to astronomers, not least because it seems to result from an active source. BepiColombo will seek to discover the origin of the magnetic field and probe the structure and dynamics of the magnetosphere.

Substance at the poles

Messenger has supported a hypothesis that Mercury has a lot of water ice at its poles, held in craters that are forever in the shadow of the Sun and so never get hot. BepiColombo is going to investigate the polar deposits to find out their composition and origin.

More about Mercury's atmosphere

We know that Mercury has a thin, atmosphere-like volume surrounding it. This is the exosphere and it contains hydrogen, helium, oxygen, calcium, potassium and water vapour. The mission will examine its composition and dynamics.

You can see the orbits that will be taken by the MMO and the MPO around Mercury

"A big surprise is why there are volatile deposits at some of the craters," says Dr Benkhoff. "We question why they are there and where they come from and that, I guess, is fascinating especially if on BepiColombo we can explain it or maybe even see changes. If there is really something active right now, we have the images from Messenger and we should in ten years' time be able to see changes or variations. We would be able to see some dynamics on the planet or on the surface." Not only will this be useful for the ESA and JAXA, but for NASA too. Any competition between them is healthy and they are each supportive of the other's ambitions.

NASA will be just as intrigued as other space agencies to learn about the cold parts of Mercury. Despite being so close to the Sun, temperatures can fall as low as -170 degrees Celsius (-274 degrees Fahrenheit), especially around craters close to the poles. Because of Mercury's rotational axis, the angle

"It's hoped the mission will enable us to learn so much more about Earth, too"

at which sunlight falls at the poles is very low over the craters, which keeps them in the shadows. "If you have some deep craters, there is never sunshine inside them," says Dr Benkhoff. "There is strong evidence that there is water ice in there. If we could prove that and measure it, it would be fantastic."

Is this a pointer to life perhaps? "In a way," Dr Benkhoff adds, although the lack of atmosphere makes it difficult for life to flourish. "Normally when you talk about life you relate it to water and of course if there is water, then you can have bacteria or whatever is related to the water. So, indeed, you could maybe have some life in these craters."

Of course, BepiColombo isn't just interested in discovering more about Mercury, though. It's hoped

the mission will enable us to learn so much more about Earth, too. On board are instruments that will gather data such as the height of the mountains, which can be used for comparison with other planets like our own.

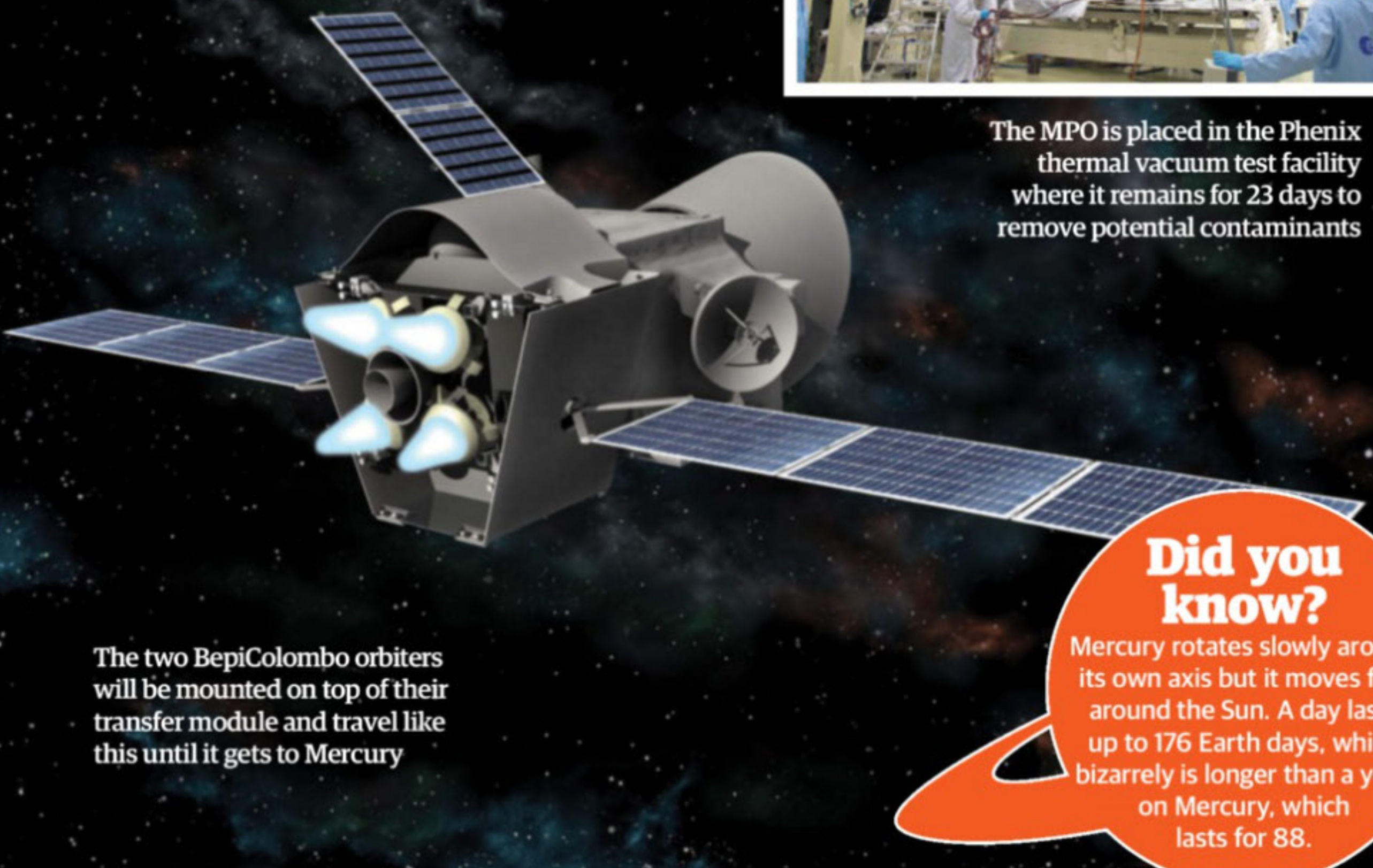
"Mercury is the only planet with an Earth-like magnetic field and so studying the affects on Mercury is like having a lab somewhere outside where we can model the interactions of a magnetic field with the Sun," says Dr Benkhoff. "We can learn about Earth... One study will look at space weather. We're protected by our atmosphere, but satellites are not. We could learn something on Mercury about the interaction between the Sun and magnetic fields, which affects the satellites."



When it arrives at Mercury in 2024, the spacecraft will separate. The transfer modules will be sent into space, while the MPO and MMO will enter into a polar orbit



The MPO is placed in the Phenix thermal vacuum test facility where it remains for 23 days to remove potential contaminants



The two BepiColombo orbiters will be mounted on top of their transfer module and travel like this until it gets to Mercury

Did you know?

Mercury rotates slowly around its own axis but it moves fast around the Sun. A day lasts up to 176 Earth days, which bizarrely is longer than a year on Mercury, which lasts for 88.

The mission will also enable scientists to observe time scales. They will be able to observe an event (such as an emission) on the Sun via the spacecraft and work out how long it takes until it reaches the Earth. It will enable better forecasts to be made. "The Americans found that processes on Mercury seem to be much faster than what we observe on Earth, so now we need to find out why," Dr Benkhoff adds. "As a result of all of this, our understanding of the Solar System as a whole will be enriched."

NASA's Messenger mission has already been helping in this regard. Before it flew to Mercury, astronomers had a good model of how the Solar System was formed, but Messenger found that the volatile content and the atmosphere on the surface of the planet was much higher than expected. It raised questions over theories of the Solar System's origin.

"What Messenger has shown is that we were correct to want to go to Mercury, because at the

beginning there were doubts: people wondered what we could learn. But there are so many unexpected results, so many new questions, that they're crying for a follow-up mission and we are now in the good position that we don't need to wait an additional 20 years to develop one. We have it in the pipeline."

There will still be a ten-year wait before astronomers are able to collate new findings, but the project is still advanced. The spacecraft, which has been assembled in Italy, is in the hands of ESA engineers and is undergoing thorough testing.

"The preparation, planning and discussion with the scientists is so important," says Dr Benkhoff. "Of course, it's not that we have to work ten hours a day over the eight years following launch, but we need to use the time correctly when we are there. I have seen how colleagues react when a mission they have waited ten years to reach comes to fruition and I'm very much looking forward to that..."

Mercury in numbers

The Sun's closest planetary neighbour has some surprising stats

1,550 km

The diameter of the largest impact crater on Mercury, the Caloris Basin.

14th century

Mercury was discovered in the 14th century BC by Assyrian astronomers.

330,000,000,000,000 kg

Its mass in billions of kilograms.

14 km

The amount the planet's diameter may have shrunk while cooling over 4 billion years.

50

One of five planets visible with the naked eye.

Number of satellites

4,879 km

The diameter of Mercury is slightly larger than Earth's Moon.

13

Mercury passes in front of the Sun 13 times every century on average.

1 It's hard to study from Earth

We don't know enough about Mercury because it's the least-explored planet in the inner Solar System. It's difficult to observe using a telescope on Earth because the Sun's bright rays cause too much stray light. Only by going there can astronomers help to eliminate that. Previous missions by NASA have thrown up some interesting insights but more information is needed and can be obtained. There are many theories that will need testing, including Einstein's general theory of relativity.

2 Why is Mercury is different?

There are four terrestrial planets: Earth, Venus, Mars and Mercury. Only the latter is an anomaly because, unlike the others, it has a metallic iron core that makes up to two-thirds of its mass (Earth's core is 32 per cent of its mass). A recent study suggests Mercury may have been stripped down and made smaller after smashing into other planets such as Earth or Venus in the past, shaving off part of its crust. A visit to Mercury is the only way of testing such theories and finding out more.

5

REASONS TO GO TO MERCURY

Why there is such great interest in going to the planet closest to the Sun

3 It can tell us how planets form

Mercury is a terrestrial planet like Earth, so sending a probe to Mercury can help us to understand how planets like our own formed over the years. It should be able to tell astronomers what forces shaped it and what general laws govern it. Life on Earth is the result of many complex forces, but only by going to similar planets, to study similar characteristics, their atmosphere and their geological past will we ever fully comprehend our own world.

4 We could map the entire planet

Although Mariner 10 in the 1970s was able to map Mercury's landscape of plains and craters, it was only able to cover around half of the planet. Messenger, sent more recently by NASA, has been able to cover more but BepiColombo will be sending two probes to circle Mercury, ensuring it is mapped more comprehensively than ever before, testing its atmosphere and magnetic field at the same time. We still don't know the origins of Mercury's field.

5 To explain its massive temperature range

Even though Mercury can get as hot as 460 degrees Celsius (860 degrees Fahrenheit), there are bright areas within craters close to the north and south poles of Mercury that indicate ice. Mercury's axial tilt is almost zero so the poles can be very chilly - as low as -180 degrees Celsius (-292 degrees Fahrenheit). By noting these extremes in temperature, astronomers can get a better insight into the inner Solar System's volatile materials.

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How big were
the dinosaurs?
Find out in issue one

big
How
were the dinosaurs?
Dinosaurs were the largest animals ever
to walk the Earth. Some of them were
taller than trees, longer than aeroplanes
and heavier than a herd of elephants.

Diplodocus
The Diplodocus was
as long as a train,
as tall as a house
and as heavy as a
double-decker bus.

Tyrannosaurus Rex
The Tyrannosaurus Rex was
as tall as a giraffe and as
heavy as an elephant.

Spinosaurus
The Spinosaurus was as tall
as a covered wagon and as
heavy as 50 cows.

Did you know?
Huge Triceratops
dinosaur fossils in France
show they weighed
about 10 tons.

Brachiosaurus
The Brachiosaurus was
taller than a 10-storey
building.

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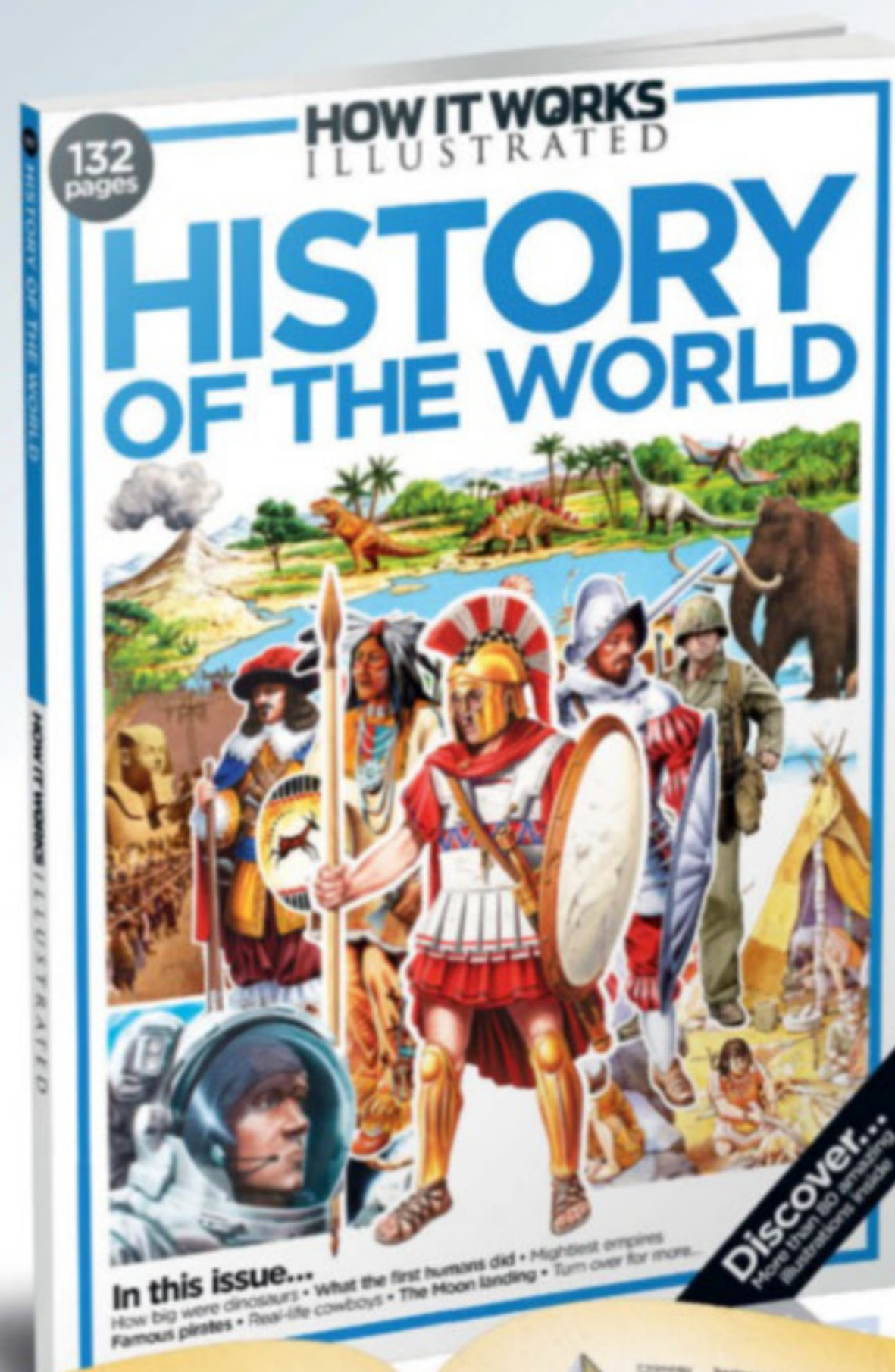
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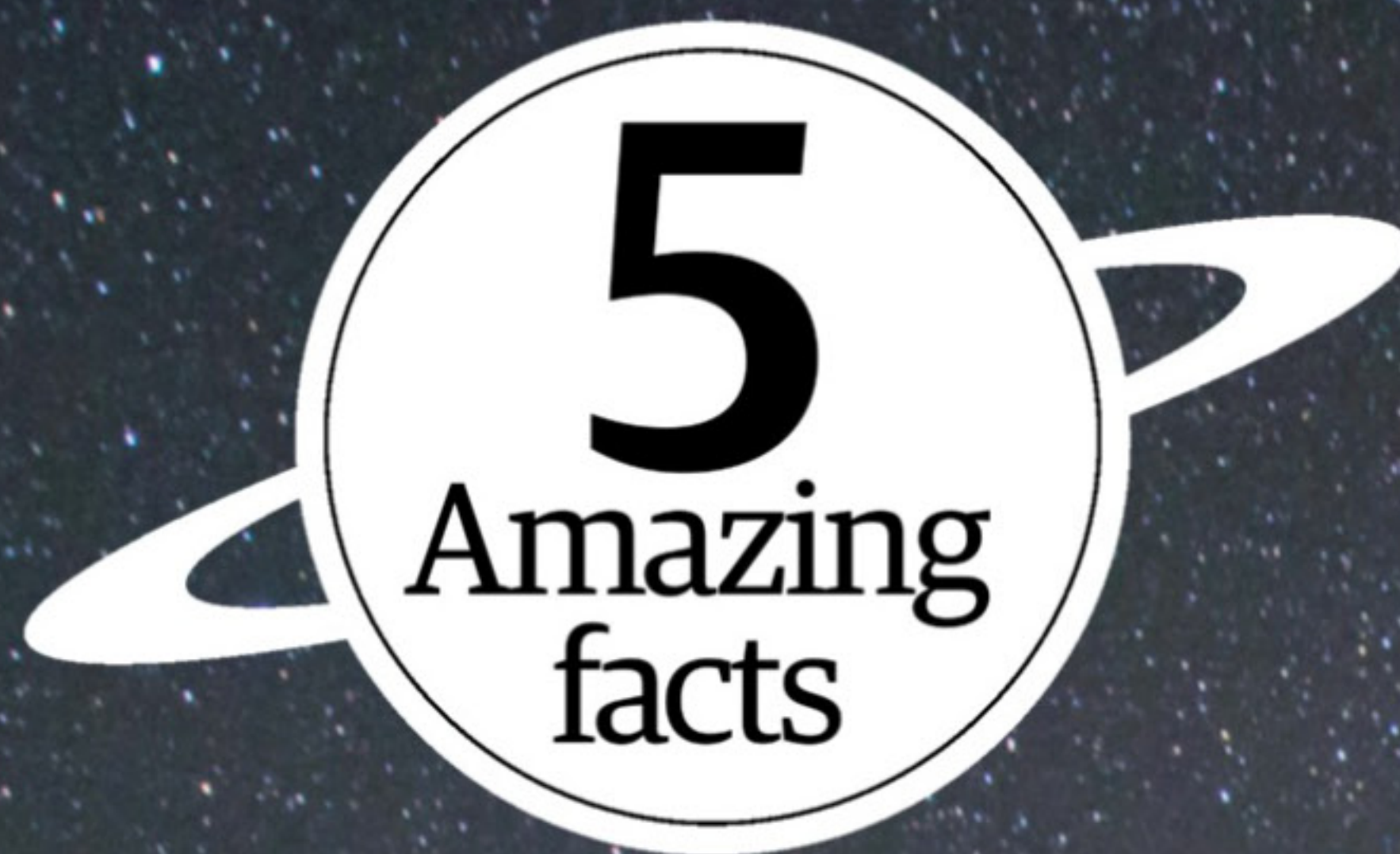
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Meteor showers

Smaller than a grain of sand

Despite the amazing light show they often produce, most meteors you see streaking through the sky range from a little bigger than the size of a grain of sand, to even smaller. The high speed at which they hit the Earth's atmosphere causes them to glow white-hot for a very brief moment, however most burn up completely before they can actually hit the Earth directly.

Meteor showers can become storms

The most-impressive regular meteor showers are the Geminids, Leonids, Perseids and Quadrantids, which at their peak can yield up to 120 visible meteors an hour. However, meteor storms can occur after the Earth moves through a relatively undisturbed trail. The Leonids meteor storm of 1966 produced a staggering 144,000 meteors an hour - that's 40 meteors shooting across the sky every second!

They're faster than our speediest spacecraft

Meteorites travel at huge speeds, anything from 11 kilometres (seven miles) per second, up to 72 kilometres (45 miles) per second. This is much faster than the fastest recorded launch speed of any spacecraft, New Horizons, which achieved a velocity of 16.2 kilometres (ten miles) per second in 2006.

Comets create meteor showers

Several cosmic phenomena can cause meteor showers on Earth but by far the most common is a comet. Every time these speeding ice balls swing around the Sun they leave a trail of tiny particles that spread out along the comet's orbital path. If the orbit of the Earth takes it through this trail, we'll get a meteor shower. These showers are predictable, occurring around the same time each year.

Other planets also have meteor showers

Meteor showers aren't exclusive to Earth, although a fairly transparent atmosphere is required to see them. You'd be able to see meteor showers across the sky on Mars, but probably not through the thick and foggy atmosphere of Venus. The thickness of the atmosphere results in different displays.



The Leonids shower occurs in mid-November and is associated with the comet Tempel-Tuttle. This annual meteor shower produces prolific meteor storms every 33 years

Flexible space suits

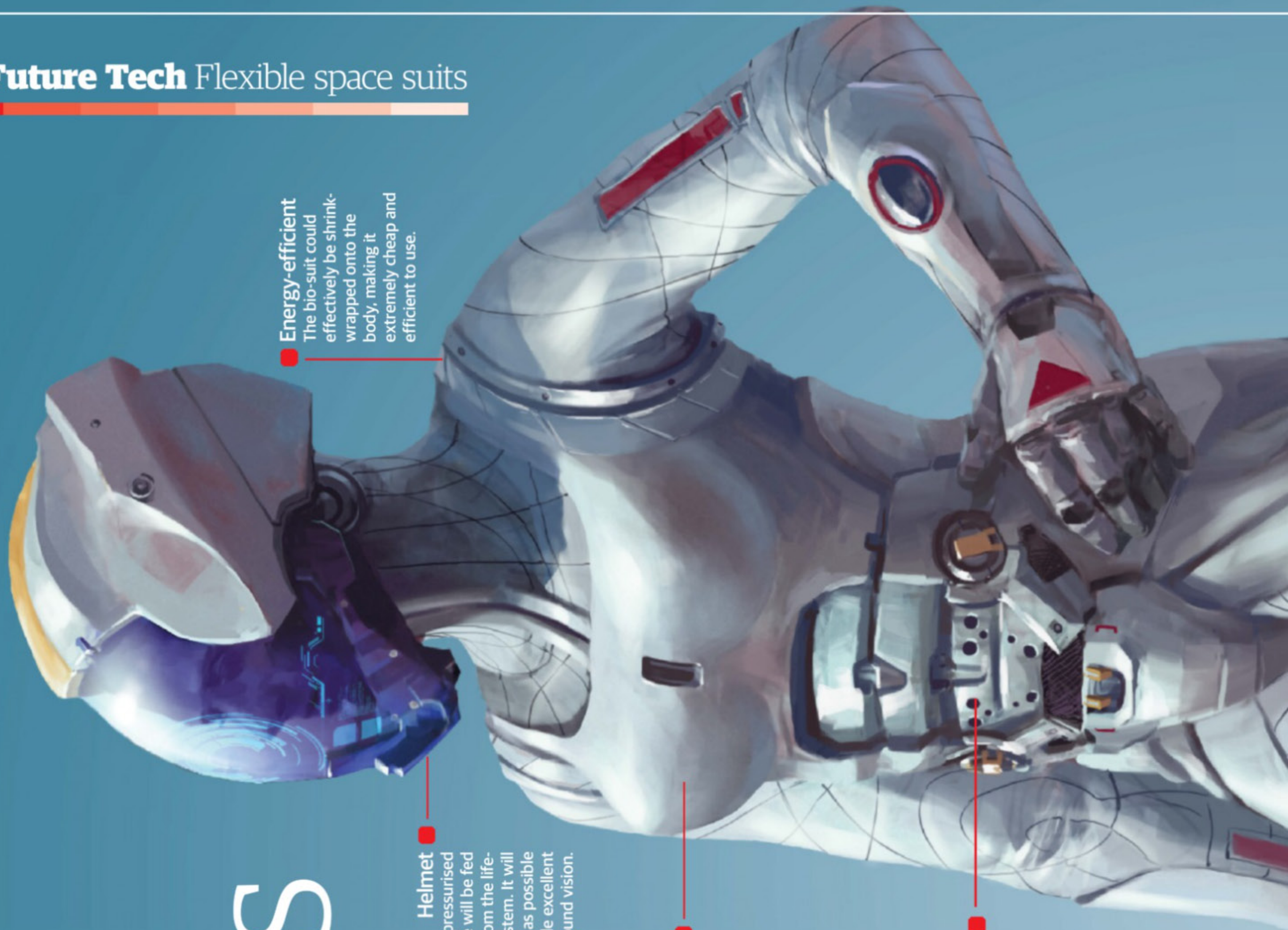
The iconic space suit, a bulky relic from the Apollo era, finally gets a long-awaited slim down

Contemporary space suits are not for the fashion-conscious. Bulky, heavy and inflexible, they nonetheless provide a vital role in keeping astronauts safe from the punishing forces experienced in space and on the Moon. Fortunately, a team has been working towards creating a space suit that will provide a better range of flexibility and comfort for future generations.

Current space suits have 14 layers, all of which provide roles such as cooling the astronaut, insulating them, as well as avoiding tears and shaping. All of this adds up to make a suit weigh over 100kg (220lbs), although this obviously doesn't affect astronauts so much when in space, due to the lack of gravity.

This new suit, being designed by a team from MIT, will have a form-fitting elastic layer, which provides counter-pressure to the astronaut by wrapping them tightly in the suit. This essentially shrink-wraps them to ensure no foreign bodies or radiation can get onto the astronaut's skin. This will replace the bulky pressurised gas systems that are being used by current space suits. Also, the suits used currently come in a one-size-fits-all format, but the new bio-suit will be as individual as it's possible to get, with each astronaut having 3D laser scans taken of their body to create the tightest-fitting suit possible.

The main layer of protection will come in the form of a rigid shell suit that will be clipped to the suit. This should be enough to protect spacewalkers from small pieces of debris. The life-support system



Helmet

This pressurised headpiece will be fed oxygen from the life-support system. It will be as light as possible and provide excellent all-round vision.

Outer shell

This firm structure is clipped to the bio-suit to protect the body against flying debris or even knocks against the spacecraft.

Life-support system

This is strapped to the hard outer shell of the suit system in order to provide oxygen and pressurised gas to the astronaut.

Energy-efficient

The bio-suit could effectively be shrink-wrapped onto the body, making it extremely cheap and efficient to use.

is attached to the shell, providing oxygen to the astronaut via the helmet as usual. The life-support system will also be used to provide additional pressure to the arms and legs.

By removing layers of protection and insulation, astronauts will have a vastly improved range of movement, making it much easier to repair things in space or perform other tasks that would previously have been hampered by decreased mobility.

A further hope for the suit is that it will work in harmony with the human body and, much like a sports compression shirt, induces a pressure on the body to mimic the effects of Earth's gravity. This would be extremely useful to astronauts who often experience bone loss and find their muscles to be weakened after returning from long space voyages. Even though the primary aim of the bio-suit is for it to be lightweight and flexible, the vastly reduced bulk could enable extras to be added to it, like communication systems and sensors, so that scientists back on Earth can get an even better idea of what pressures the human body undergoes when in outer space.

Estimates suggest that we are still about ten years away from a fully operational bio-suit, but the potential for a lightweight, flexible suit is an exciting prospect. It's a future technology that NASA clearly agrees with, as its NIAC (NASA Innovative Advanced Concepts) arm has provided funding to the project. A second-skin space suit like this would greatly enhance the capacity of astronauts to take on projects in space that are currently too intricate or risky using current technology. The suit's suitability in dusty environments could also make it an ideal option for working on Mars. Who knows, this could well be the space suit that the first astronaut on the Red Planet will be wearing the day they make that historic first step. ●

“This could well be the space suit that the first astronaut on the Red Planet will be wearing”

Fitted suit

3D laser scans will be taken of an astronaut's body so the team can create a personalised suit that fits without any depressurising gaps.

Lightweight

The suit is designed to be as light as possible, making space walks a much more comfortable experience and enabling trickier tasks to be carried out.

Extra skin

The tight-fitting nature of the suit will improve muscular performance and endurance as well as blood circulation.

Added extras

The bio-suit would enable scientists to add extra technologies, which is impractical on current space suits due to their weight and bulk.

Counter-pressure

The suit is wrapped tightly in order to provide counter-pressure – a crucial part of keeping astronauts alive during space walks.

Gloves and boots

These will be equally tight-fitting and will be pressurised by regular gas boosts from the life-support system to keep astronauts comfortable and, more importantly, alive!



COLOSSAL COSMIC COLLISIONS

Planetary poundings, stellar smash-ups and great galactic crashes, All About Space explores some of the greatest collisions the universe has ever witnessed

Written by Gemma Lavender

Bumper cars at a fairground, dropping an egg on the floor, or the devastating crash between vehicles on a motorway – we have all witnessed a collision between objects at some point in our lives. On Earth, these events seem to happen rapidly, but in space it's a whole different ball game.

Despite often being separated by many thousands of light years, collisions on this huge scale have altered entire regions of space in the past and will continue to do so in the future.

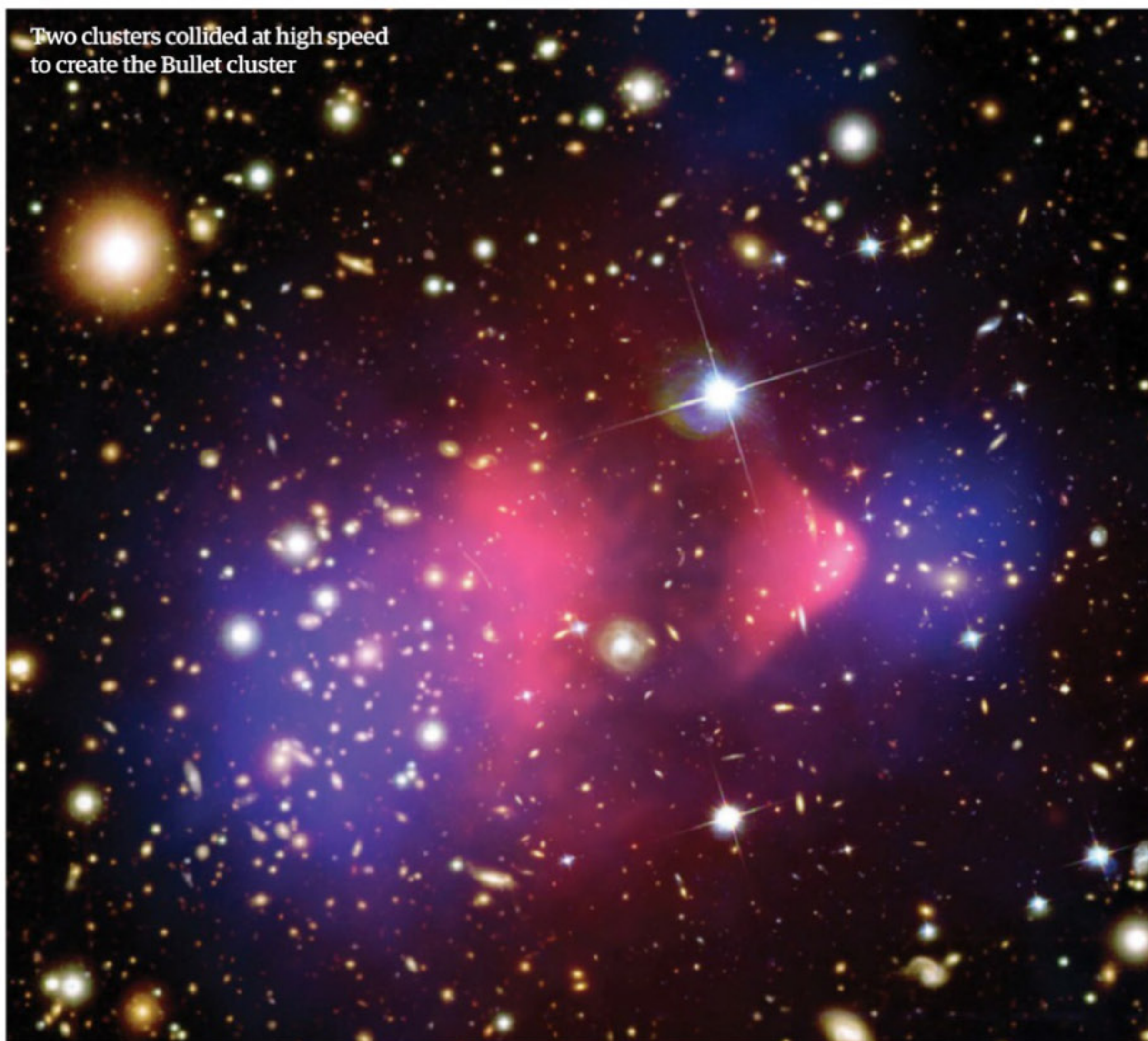
Of course, comparatively smaller collisions have also played their part. The devastating, yet lucky,

collision between Earth and an asteroid roughly 65 million years ago is an impact we very much owe our existence to. This great lump of space rock brought so much energy to a younger Earth and ended the lives of many of the dinosaurs to make way for the evolution of man.

Even tiny, man-made impacts that happen against all odds serve to remind us that, in the huge scale of the universe, even the most unlikely violent meetings can and probably will happen. From the crash of worlds, to the slow and steady joining of galaxies, these are the biggest collisions ever. ■



Two clusters collided at high speed to create the Bullet cluster

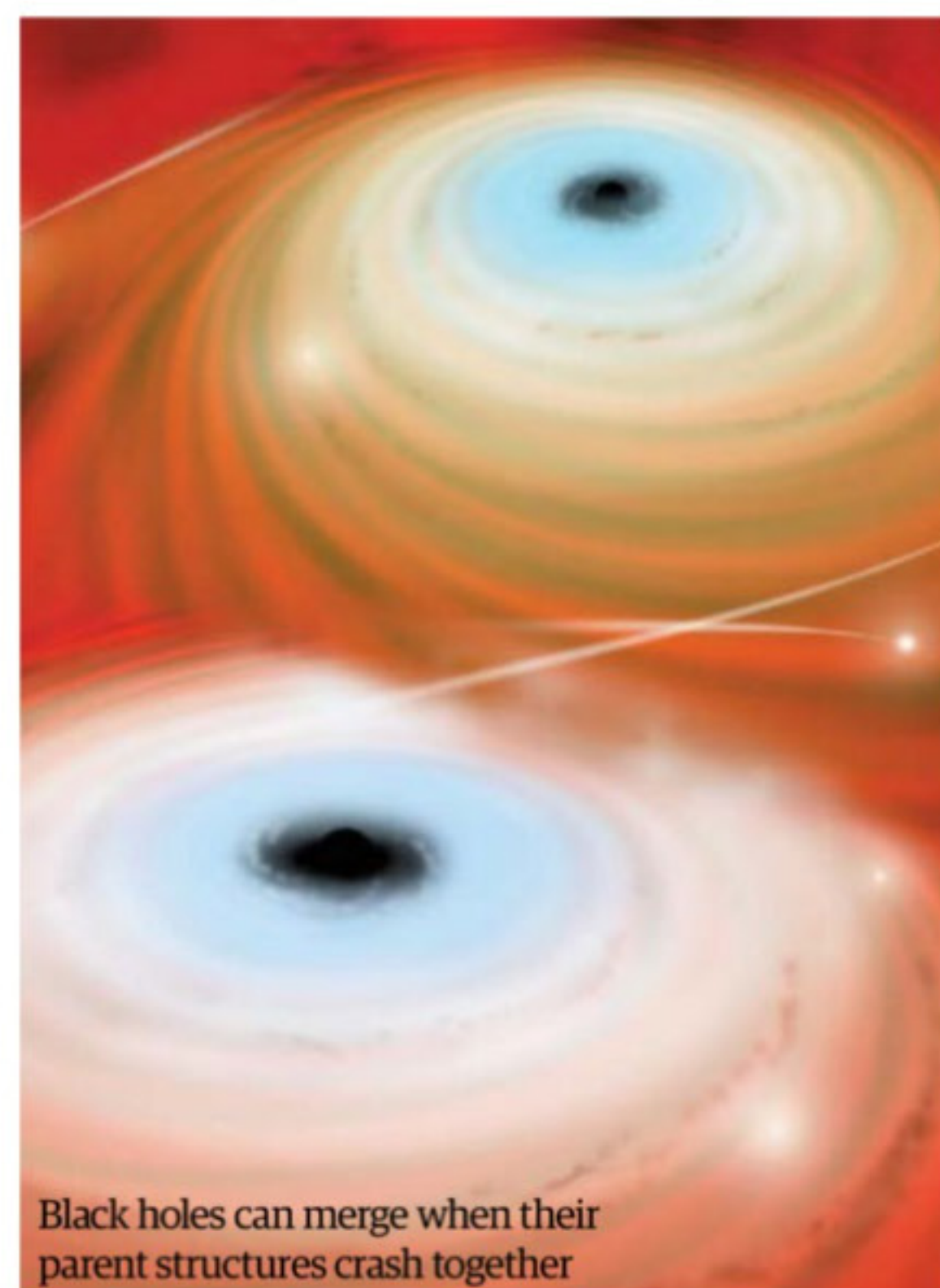


1 Supermassive smash-up

We can see what happens when galaxies collide, but what about when the black holes within them merge? These high-gravity objects can be hundreds of millions of times more massive than the Sun, placing them in the supermassive category. When their parent galaxies merge, the black holes at each of their centres get closer and closer, spiralling around each other until they coalesce and become one, unleashing invisible yet extremely powerful gravitational waves that ripple through space.

The crash gives the combined black hole a kick in one direction and at speeds of up to 5,000 kilometres (3,100 miles) per second, it can recoil straight into intergalactic space, dragging a cluster of stars with it.

"It can recoil straight into intergalactic space"



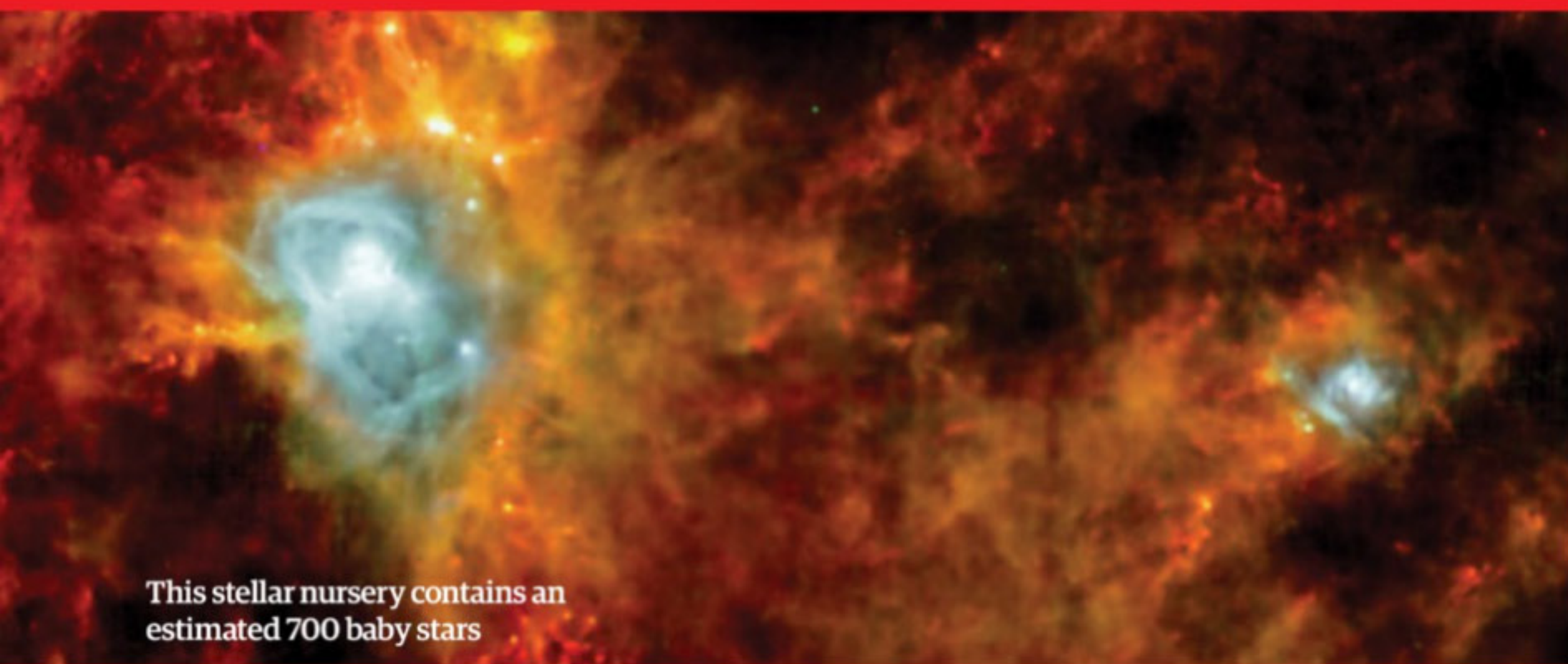
Black holes can merge when their parent structures crash together

2 A catastrophic meeting of giants

The Bullet cluster serves up one of the best examples of a great collision, as a pair of giant clusters teeming with galaxies smashed into each other in a merger hundreds of millions of years in the making. Astronomers have estimated that this truly gargantuan collision, some 3.7 billion light years away from the Solar System, is the biggest cosmic event since the Big Bang.

The impact between this glut of galaxies is so tremendous that both the normal matter we can see - the parts of the universe we're able to observe - and the elusive dark matter, have been wrenched apart. Experts are able to see where this dark matter hides by the way its gravity bends the light of more-distant galactic structures. Meanwhile, colliding gas clouds are heated to millions of degrees as they sizzle in X-rays.

This stellar nursery contains an estimated 700 baby stars



3 An ambush of dark matter

All around the Solar System is a giant loop of stars and star formations in the ghostly shape of nebulas. Scientists think this ring - the Gould Belt, which is 3,000 light years across - originated when a giant clump of dark matter fell onto the Milky Way around 30 million years ago and collided with a giant cloud of molecular hydrogen gas. The impact caused the Milky Way to see more stars, literally, as the gas then collapsed and hot stellar infants were formed. Ripples spread out from the epicentre of the collision and we see one of those ripples today - in the form of the Gould Belt.

■ **Young Earth**
Material ejected
4.5 billion years
ago is thought to
have merged to
form our Moon.

■ **Theia**
About the size of
Mars, Theia could
have smashed
into Earth during
its younger years,
striking it with a
glancing blow.

4

The impact that made the Moon

The making of our Moon wasn't a gentle process. Some 4.5 billion years ago our Solar System was nothing but a youngster - freshly made from a swirling cloud of dust, gas and space boulders in orbit around our equally young Sun. Our system's adolescent years were unsettled and almost acting out in a fit of turbulence. Other worlds and rocky debris regularly rolled through our star's local

neighbourhood, but it would be the stray Mars-sized Theia that was set to make all the difference to our planet.

Like a cue ball that slowly creeps across a snooker table to pot another, Theia is thought to have smacked into Earth at an angle of 45 degrees. Its relatively moderate speed, astronomically speaking, did nothing to lessen its huge impact.

5 The day Earth got bombarded

We constantly run the risk of being hit by an asteroid and we're quite often reminded of that every time a huge chunk of space rock buzzes past our planet. More worrying is the possibility that we could end up in the path of one that's big enough to take out human civilisation and most of life on Earth - similar to the impact event that smashed into our planet and wiped out the dinosaurs.

The creatures that were around in this chapter of Earth's history witnessed the wrath of a bolide, about ten kilometres (six miles) wide, which left its imprint in the form of what we now know to be the

180-kilometre- (112-mile-) wide Chicxulub Crater. It's thought the crash released more than a billion times more energy than the bomb that obliterated Hiroshima, Japan. What followed was a flaming, red-hot sky and an atmosphere full of dust as the tops of the oceans hissed and boiled off under the intense heat. Vaporised rock was sent into the atmosphere, which then encircled the globe and condensed into liquid droplets before falling to the ground.

Recent studies have found that an asteroid even bigger - around 37 to 58 kilometres (23 to 36 miles) larger than the one that caused this mass extinction

- belted the Earth around 3 to 4 billion years ago. This would have been during the tail-end of the Late Heavy Bombardment period that saw dozens of gigantic asteroids rain into our Solar System, creating the many scuffs and craters on rocky bodies like Mercury and the Moon. Crashing through the atmosphere at an estimated 20 kilometres (12.4 miles) per second, this gargantuan piece of rock was able to create a 10.8-magnitude earthquake that set off further tremors, propelling tsunamis hundreds of kilometres high, which swept across the majority of our young planet's landmass.

6 Richest collision in space

When a pair of neutron stars dance, they dance to the death. Stuck in an ongoing, deadly, orbital tango, these dense stellar remnants will spiral in towards each other.

When they eventually collide it's so catastrophic that a magnetic field trillions of times stronger than that of Earth's erupts from the collision in a matter of one or two thousandths of a second. A black hole can be cooked up in this high-energy event, provided there's enough mass.

Some astronomers believe that these kinds of events make some

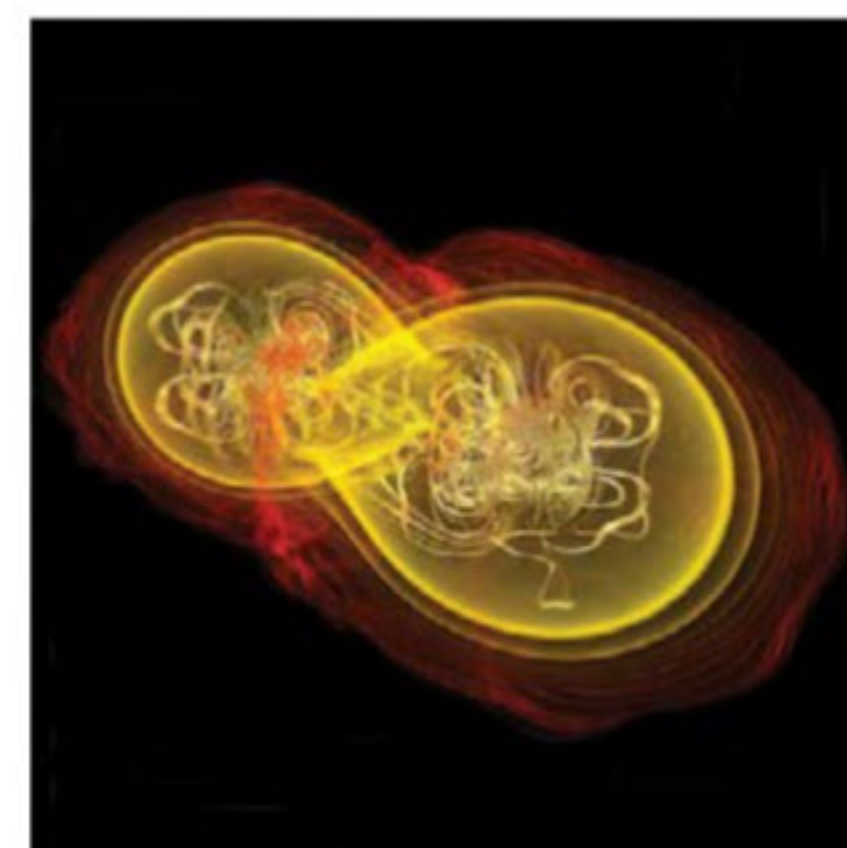
types of gamma-ray bursts, the flashes of extremely energetic explosions that are one of the brightest electromagnetic events known to occur in the cosmos.

Using the likes of the Hubble Space Telescope to observe these objects, they have theorised that the events are energetic enough to create precious metals such as gold, along with other dense elements. It's possible that the combined teamwork of a pair of neutron stars could explain the precious metals that can be found knocking around space.



1 Gamma-ray burst-maker

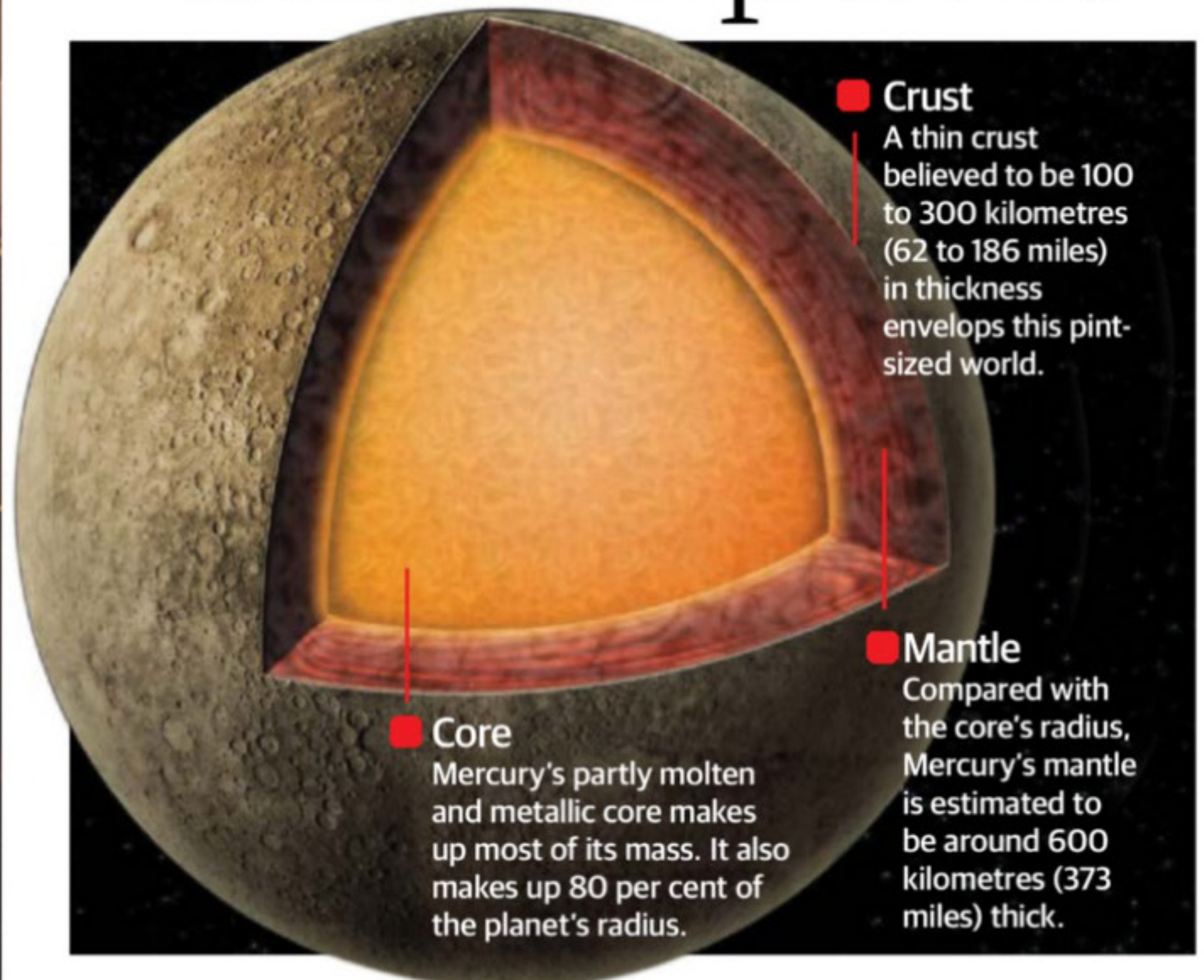
As well as precious materials, two neutron stars that are set to merge also create short bursts of gamma rays.



2 Quick merge

Crashing into each other, the neutron stars create a rapidly spinning black hole and cause the event horizon.

7 Mercury: hit-and-run planet

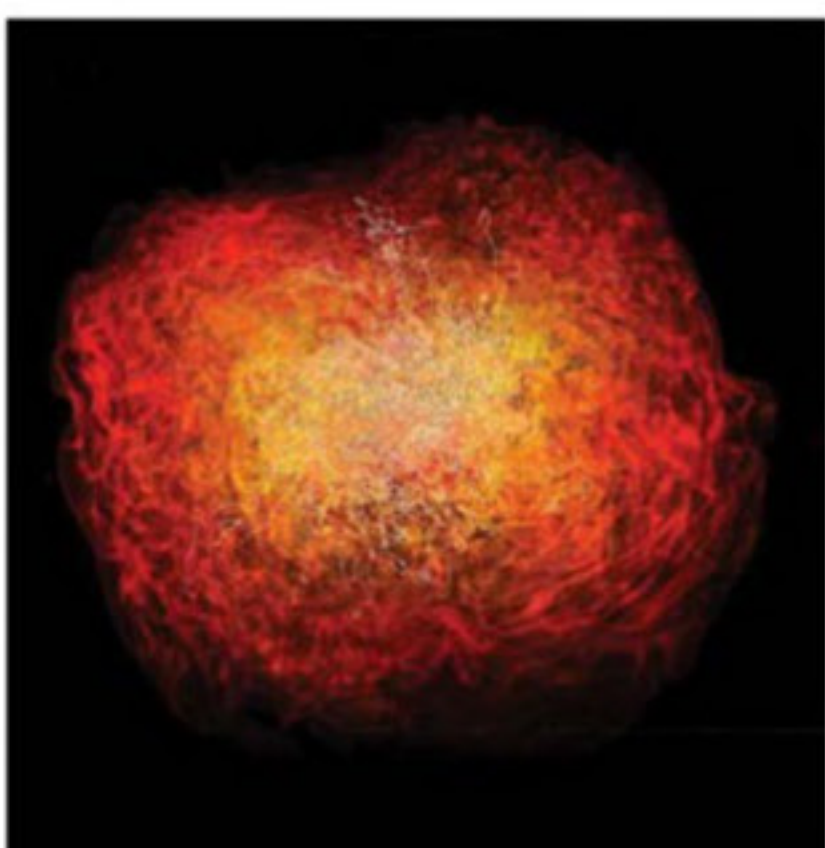


How Mercury was cobbled together has mystified astronomers for many years. What's left them scratching their heads for so long is its unusual make-up. This small world isn't made of material like the other planets in our Solar System - Mercury is unusually metal-rich, with its iron core making up about 65 per cent of its bulk. When you compare that with the Earth's core, which pales in significance at 32 per cent of our planet's mass, you can see why the question of Mercury's formation has caused much confusion in the scientific community.

Recently astronomers have produced another theory. The general consensus is that this Sun-worshipping planet must have lost the majority of its mantle to expose a metallic core. Picturing how it did this, while retaining the noticeable levels of volatile compounds it clings to today, conjures an image of a young, reckless, runaway Mercury, smashing into whatever planet or lump of space rock that got in its way.

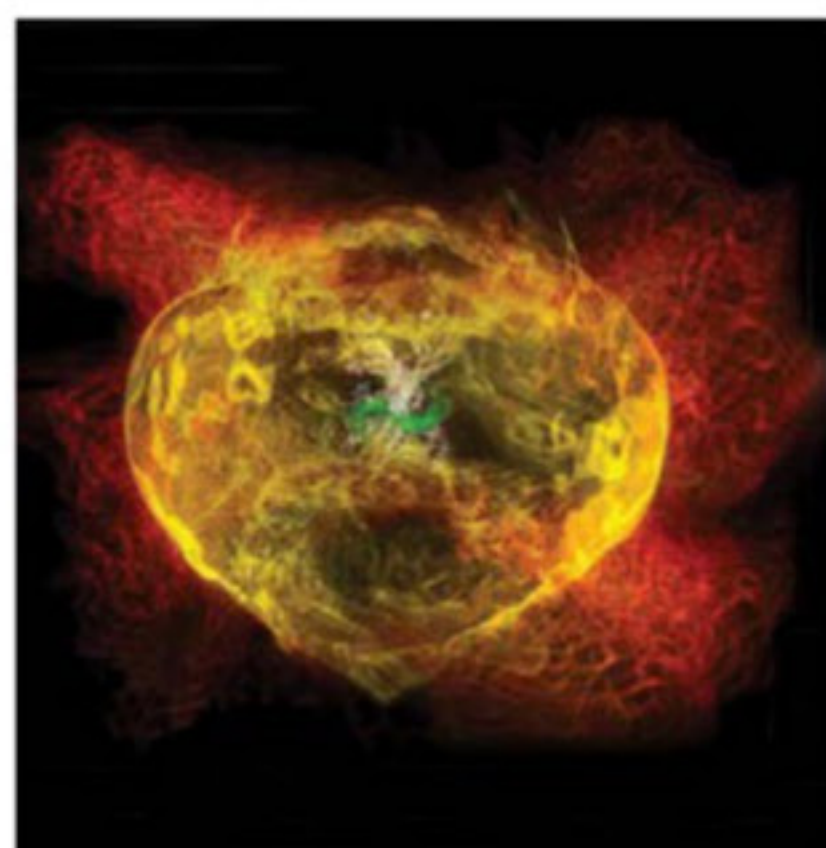
The University of Bern's Erik Asphaug and Andreas Reufer suspect that proto-Mercury lost half of its mantle in a hit-and-run collision, when it smashed into a larger planet - possibly a proto-Venus or proto-Earth. It's also likely Mercury was a repeat offender, crashing into larger planets more than once.

If a major asteroid impacted on Earth today, it could cause another mass-extinction event, devastating most life on the planet



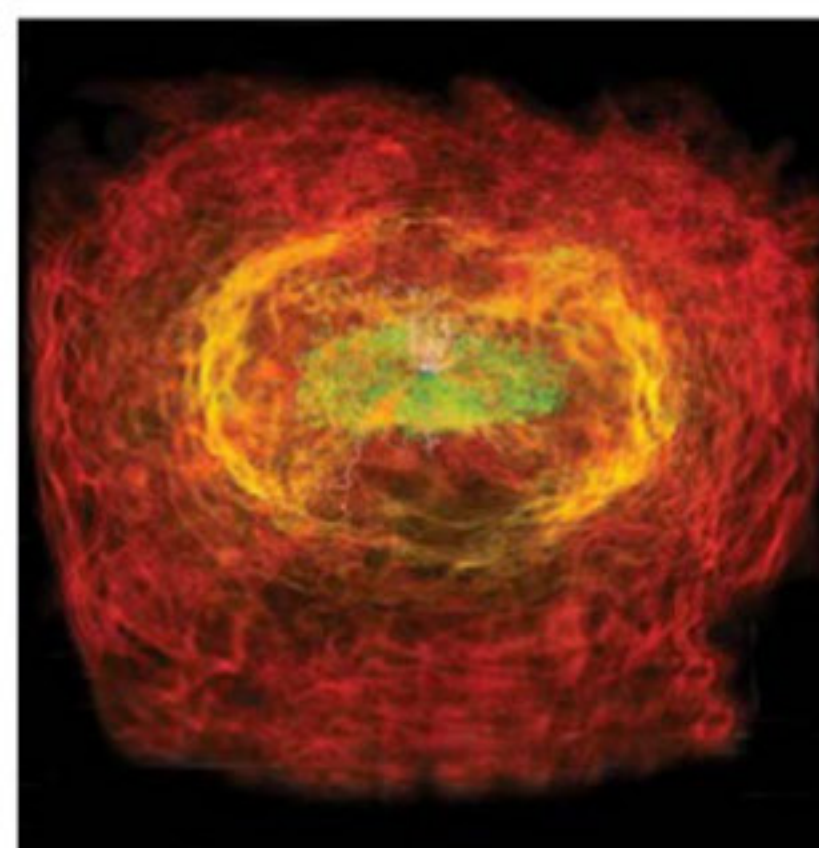
3 Swirling chaos

Super-dense matter and temperatures begin to swirl around the new black hole, amplifying the magnetic field.



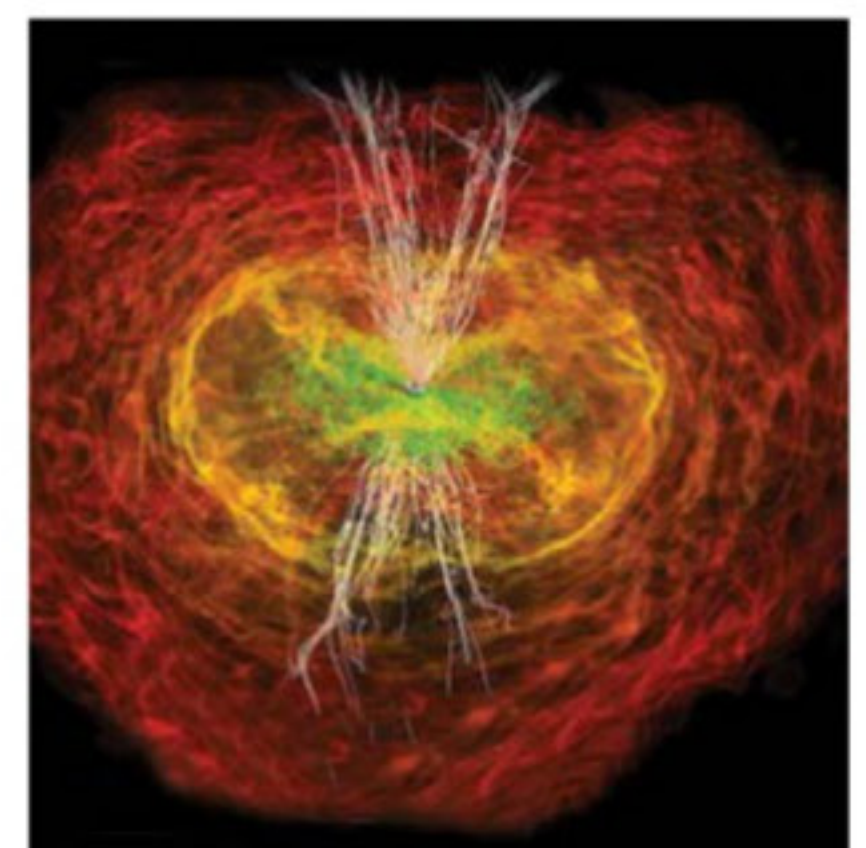
4 Magnetic pump up

Swirling gas builds up the magnetic field, with a strength thousands of times stronger than the original fields.



5 Organised field

The field becomes more organised and gradually begins to form a pair of outwardly directed funnels.



6 Powerful gamma-ray bursts

This configuration is exactly what is needed to power jets of fast particles that produce short gamma-ray bursts.

Colossal cosmic collisions

Billions of years into its future, the Milky Way and Andromeda will collide

2. Our Milky Way

The stars are so spaced out in both galaxies that the likelihood of them crashing into one another is very slim.

1. On a collision course

Both the Milky Way and Andromeda are racing towards each other at about 110 kilometres per second (68 miles per second).

4. Our closest spiral

Collisions aren't new for Andromeda and it's thought to have collided with another galactic structure in its past.

8 Milky Way's violent fate

A good four billion years from now, our galaxy is going to undergo a huge change. While we see galaxies rushing away from us as the universe expands, Andromeda is looking to collide with the Milky Way at a speed of around 110 kilometres (68 miles) per second. With the one trillion stars of the nearest galactic spiral joining forces with the 300 billion of our home galaxy, you would expect a collision of epic proportions.

Since the stars in both galaxies are so far apart, there are unlikely to be any stellar smash-ups and

it's been estimated that there's a 50 per cent chance our Sun could be thrown from its current position and violently swept out three times further from the Milky Way's centre.

There is also a possibility our Sun and its planets could be ejected by the crash and out of the newly formed giant galaxy, Milkomeda. While it has been speculated that mankind will never see the spectacle, because by that time the Sun will have heated the Earth past the point that life could exist, it's thought that in all likelihood our Solar System

will remain largely unaffected, whatever this cosmic event has in store.

On the flip side, when it comes to colossal collisions, this will be quite a thing to see. While both galaxies have had their fair share of galactic (albeit smaller) rucks with some nearby structures, the merger of both galaxies' supermassive black holes will pack a punch. It will be a multi-million-year process with a powerful blast of gravitational waves and electromagnetic radiation that could create a quasar to boot.

3. Milkomeda
When the pair merge, what is known as Milkomeda will form – about 4 billion years from now.

6. Late to the party
It's thought a third galaxy, the Triangulum, will orbit Milkomeda before merging further into the future.

5. Meeting of two giants
The supermassive black holes found at the hearts of both galaxies will merge, causing stars within both galaxies to be transferred to higher orbits.

The Solar System's fate

Earth will be largely unaffected by this mammoth collision

- The Sun's place
Our Sun's position in the Milky Way today

A new path
Our Sun could follow a similar orbit around the centre of Milkomeda.

Before the impact, experts had predicted that the satellites would miss each other by 0.5 kilometres (0.3 miles) and the chance of them colliding was about one in 50 million. The accidental crashing of two or more artificial satellites will almost certainly happen again, but pinpointing where and when is anyone's guess.



The debris from their spectacular deaths has fallen onto the white dwarf and scientists are able to detect the chemical signature of rocky elements like iron and nickel in the atmosphere. This might be something that our Solar System has to look forward to when our Sun undergoes its death throes.

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Space engine of the future?

Could the engine of our science-fiction dreams be sitting in Portsmouth, UK?

Wings and tail

Although the vehicle would float around on its EmDrives, the wings and tail mean it can still come back as a glider if it lost all electrical power.

Orbital engine

Once the spaceplane has reached orbital altitude, this EmDrive will push sideways to accelerate the craft up to orbital velocity, more than 29,000 kilometres (18,000 miles) per hour, so that it will stay in space.

Lift engine

This EmDrive unit provides the vertical thrust to levitate the spaceplane. This will push it up on a gentle climb to orbital altitude.

Manoeuvring thrusters

Smaller versions of the EmDrive thruster can also be used to enable the spaceplane to change its orientation without expending propellant.

Liquid hydrogen tank

LOX tanks

These small tanks contain liquid oxygen that can also contribute to cooling the EmDrive, while producing oxygen gas for the electricity-producing fuel cells.

Fuel cells

First used in the Apollo Moon programme, these reactors make electricity by combining hydrogen and oxygen into water and will use the hydrogen boiled off through keeping the EmDrive cool.

■ Liquid hydrogen tank

These highly insulated tanks hold liquid hydrogen. This would be used to both keep the superconductors cool and then feed the fuel cells.

■ LOX tanks

■ Lift

The resonating microwaves within the EmDrives would produce the thrust to lift and push the spaceplane.

“Because the microwaves move at light speed, they must be considered under Einstein’s theory of relativity”

The EmDrive is the brainchild of microwave engineer Roger Shawyer, who after 40 years with aerospace giants Sperry, BAE Systems and Astrium set out to pursue a remarkable idea: a thruster that can produce a force without any exhaust. The problem with rockets is they need a reactive mass, something to throw away, so if you’re going to Mars you have to take all the propellants you’re going to need for the whole flight with you.

Shawyer’s design is controversial, but it all comes down to one point of contention. The thruster consists of a closed tapering box and microwaves beamed into the box bounce back and forth between the ends, with every bounce producing a small force. The ends are also shaped so the microwaves are focused away from the walls. This radiation pressure is accepted, it’s how solar sails work, but now things get counter-intuitive.

People have trouble getting away from the image of a gas trapped inside the thruster. If it were gas molecules in there, you couldn’t focus them to prevent them hitting the walls. Even if you could, you’d just get a high pressure on the small end and a low pressure on the big end that balances out.

Radiation pressure is different, however, because electromagnetic radiation moves at light speed. This means the force produced per bounce depends on the average speed of the microwaves in the box. If half the microwaves are going in each direction, they are moving at the speed of light but the average speed is zero - and this group speed can be manipulated. If the width of the small end is smaller than the wavelength of the microwaves, it reduces the group speed relative to the big end, so the big end makes a bigger force.

The final step that Shawyer maintains, and the one that causes controversy, is that because the microwaves move at light speed, they must be considered under Einstein’s theory of relativity, where each end of the box has its own valid point of view. This would mean that, as far as the universe is concerned, the thruster is an open system and able to produce thrust. A good analogy is that the trapped microwaves provide an anchor point to push off space itself.

So far Shawyer has created thrusters made of copper that appear to confirm the theory, and since his initial work a group at NWP University in China has been carrying out independent trials that also agree with his research. But the sheer audacity of a propellant-free thruster has kept a barrage of scepticism coming.

Copper thrusters could have a massive market in satellite-maneuvring, but they only produce 20 grams (0.7 ounces) of thrust per kilowatt of power put in and this is because energy is lost with every bounce. But if the thruster were made from a superconductor, no energy would be lost in reflection and the system could produce three tons of thrust per kilowatt.

This would enable the future we’ve been promised, with flying cars and easy trips to space - so these superconducting thrusters are now Shawyer’s focus. Groups in China and the US are also pursuing similar thrusters, so he’s hopeful that either he or one of the outside researchers will be able to prove the concept within a few years. ■





All About... EARTH'S SUPERNOVA NEIGHBOUR

As astronomers watch the story of SN1987A unfold before their eyes, they are observing the closest supernova in living history and gradually uncovering its turbulent past

Written by Laura Mears

All About Earth's supernova neighbour

When SN1987A exploded in 1987, no one was expecting the blast. The star behind it all, an unassuming blue supergiant, was an extremely unlikely candidate for a supernova, so when it happened every scope in the Southern Hemisphere turned to face the Large Magellanic Cloud (LMC).

This irregular galaxy is less than 200,000 light years from the Sun, making it one of the closest galaxies to the Earth. It measures around 14,000 light years across at its widest point - around an eighth of the diameter of the Milky Way. Located in the southern sky, between the constellations Dorado and Mensa, the LMC is visible all year round from latitudes below 20 degrees south. It appears as a faint white smudge around 20 times the total width of the full Moon.

The LMC is actually a satellite trapped in orbit around the Milky Way and with a total mass no more than a hundredth of its captor, the galaxy is a relative dwarf. Although it has an obvious bar of stars in the centre, the gravitational pull of our own galaxy has distorted its structure, and tidal interactions with the nearby Small Magellanic Cloud have created a bridge of gas between the two.

The local disruption fuels the star formation, so the LMC contains several bright clouds of molecular gas including the Tarantula nebula, which is home to some of the most massive stars in the known universe. Large stars burn through their fuel rapidly, collapsing in a dramatic blaze and scattered across the field of molecular gas are the remnants of dozens of supernovae. However, none is quite so interesting as SN1987A.

On the very outskirts of the nebula is a young star cluster that formed around 12 million years ago. Here, 500 Sun-sized stars are joined by 12 massive blue supergiants and nestled among them is SN1987A, the closest supernova to be witnessed since the invention of the telescope.

SN1987A was a red supergiant, before losing some of its mass to become a blue supergiant similar in size and brightness to its companions. However, as it neared the end of its life, the star underwent a catastrophic collapse.

On the night of 23 February 1987, a research assistant from the University of Toronto set up a routine long-exposure image of the LMC - but when he developed the plate, something was different. A new, extremely bright star had appeared in the image. By morning, two other astronomers had also spotted the supernova and news rapidly spread to observatories across the world.

The explosion produced radioactive nickel and in the three months following the initial blast, the brightness of SN1987A grew steadily as the metal decayed into cobalt and then iron. At its brightest, it reached an apparent magnitude of three, making it visible with the naked eye even in a brightly lit city.

Despite its brightness, SN1987A was difficult to view from the ground, and it wasn't until the launch of the Hubble Space Telescope in April 1990 that astronomers were able to get a closer look at the young supernova. It's now the best-studied supernova in history and astronomers will have a front-row seat as the collapsed star continues to evolve in the coming years. ■

Where is SN1987A?

The surprising SN1987A supernova was traced to the outskirts of the Tarantula nebula

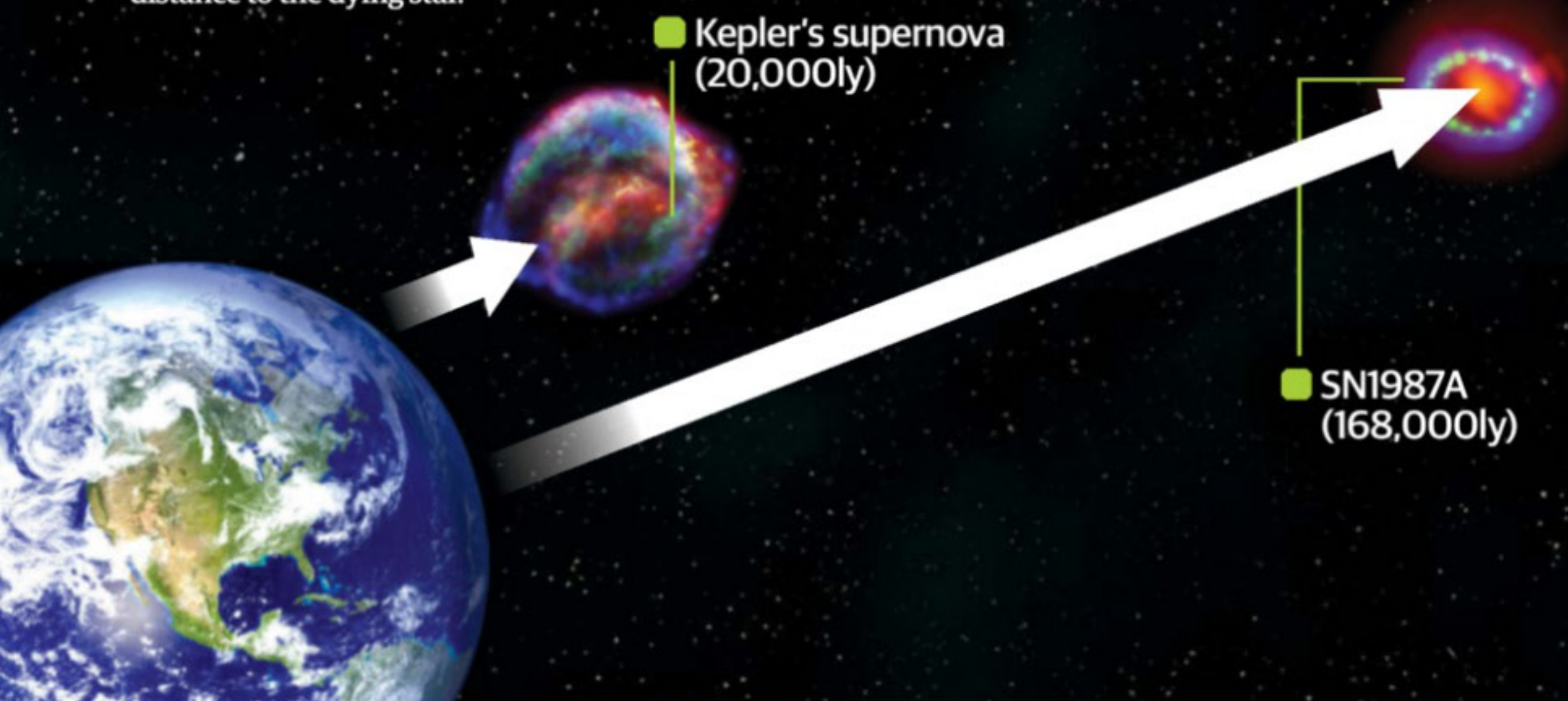
The Tarantula nebula is one of the brightest nebulae in the sky. It is also one of the most active areas of star formations in nearby space, where the twisted clouds of partially ionised hydrogen gas conceal over 800,000 stars.

The nebula is littered with the remnants of burnt-out supernovae. Individual star clusters formed sporadically, bursting into life as massive supergiants, racing through their fuel and then dramatically disappearing in a shower of gas and radiation, but SN1987A is unique. It's the closest supernova to Earth to have exploded since the invention of the telescope and we have learned more from it than from all of the older remnants in the Tarantula nebula combined.

Too close for comfort?

SN1987A is not the closest supernova ever witnessed. In 1604, Kepler's Supernova exploded inside the Milky Way, just 20,000 light years from the Earth. In the absence of modern technology, the aftermath of this phenomenal event could only be recorded from the ground. The unusual ring structure surrounding SN1987A was key in determining its distance from the Earth.

The inner ring lit up a year after the initial explosion, setting its radius at one light year. By drawing an imaginary triangle between the edge of the inner ring, the supernova itself and the Earth, astronomers were able to use trigonometry to calculate the distance to the dying star.



R136a1

The Tarantula nebula is also home to the most massive known star. R136a1 is an astonishing 265 times the mass of the Sun.

NGC 2060

Near the centre of the nebula is the NGC 2060 cluster, containing a 5,000-year-old supernova remnant.

SN1987a

Earth's closest supernova is located on the outer edge of the nebula, in a cluster of other blue supergiants that all formed around 12 million years ago.

Inside and out

SN1987A's 27-year evolution has changed the way we think about supernovas

By the late 1980s, there was already a theoretical model predicting the aftermath of the death of a massive star, but none had ever been observed up close. The fresh explosion of SN1987A offered astronomers a rare opportunity to watch a cosmic event unfold in real-time, over the course of years, not centuries – but this supernova was unusual.

The catalyst star of SN1987A, Sanduleak -69 202, didn't fit the profile of a star about to collapse. It was a blue supergiant of around 20 times the mass of the Sun, not the red supergiant that scientists were expecting. It was also surrounded by three distinct rings of glowing gas, created several thousand years before the star died.

These unusual halos have enabled astronomers to track the progress of the shock wave as it races

away from the supernova, lighting up like a beacon whenever a collision occurs. The rings themselves are moving away from SN1987A at the (relatively) slow speed of around 160,000 kilometres (100,000 miles) per hour, but the debris from the explosion is moving at least 100 times faster.

When the star ran out of fuel and the core collapsed, a fraction of the energy from the explosion escaped, racing through the gas rings and causing them to glow. After this initial hit, the light faded. But in 1997, the debris from the supernova started to catch up with the inner ring. A single spot of bright activity appeared on the north side and by 2000 there were several more to the south.

As the debris ejected from the centre of the explosion collided with the hot plasma, the impact

created shockwaves, releasing bursts of X-rays. The radiation excited the gas and dust in the debris cloud, causing it to glow. That was just the beginning – in 2011 the bulk of the debris began to slam into the inner ring, lighting up the entire circumference and as the main front of the shockwave continues to collide with the remnants of the ring, the material will eventually be blown away into the LMC.

What will remain of SN1987A is currently unknown. During a supernova explosion, the matter that once made up the core of the star collapses inwards, compressing together so tightly that the protons and electrons are combined to form an incredibly dense object known as a neutron star. However, so far the remains of SN1987A are curiously missing entirely.

Supernova signature

Key features of this stellar gravestone

1. Debris

A cloud of dust and gas from the remnants of SN1987A is expanding outwards from the centre, rushing towards the inner ring at 32 million kilometres (20 million miles) per hour.

2. Inner ring

The bright inner ring surrounding SN1987A was formed around 20,000 years before the catalyst star turned supernova. It measures roughly one light year across.

3. String of pearls

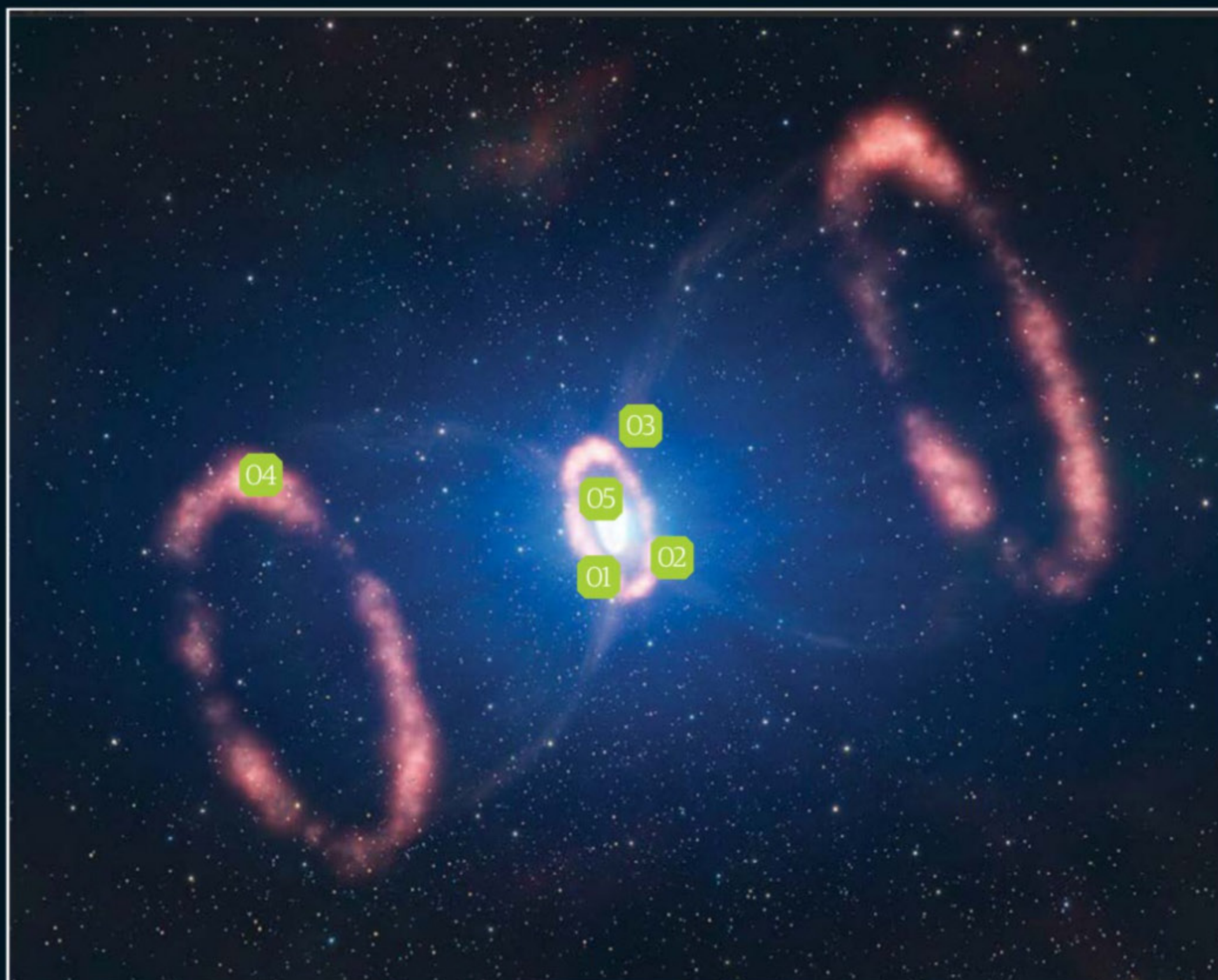
As clumps of debris collide with the ring, they create a shock wave, leading to the release of X-rays, which make the dust and gas glow.

4. Outer rings

Although the outer rings appear offset from the centre of the star, this is an illusion based on our relative positions in space. In reality, the two rings lie in a straight line, one in front of SN1987A and the other behind.

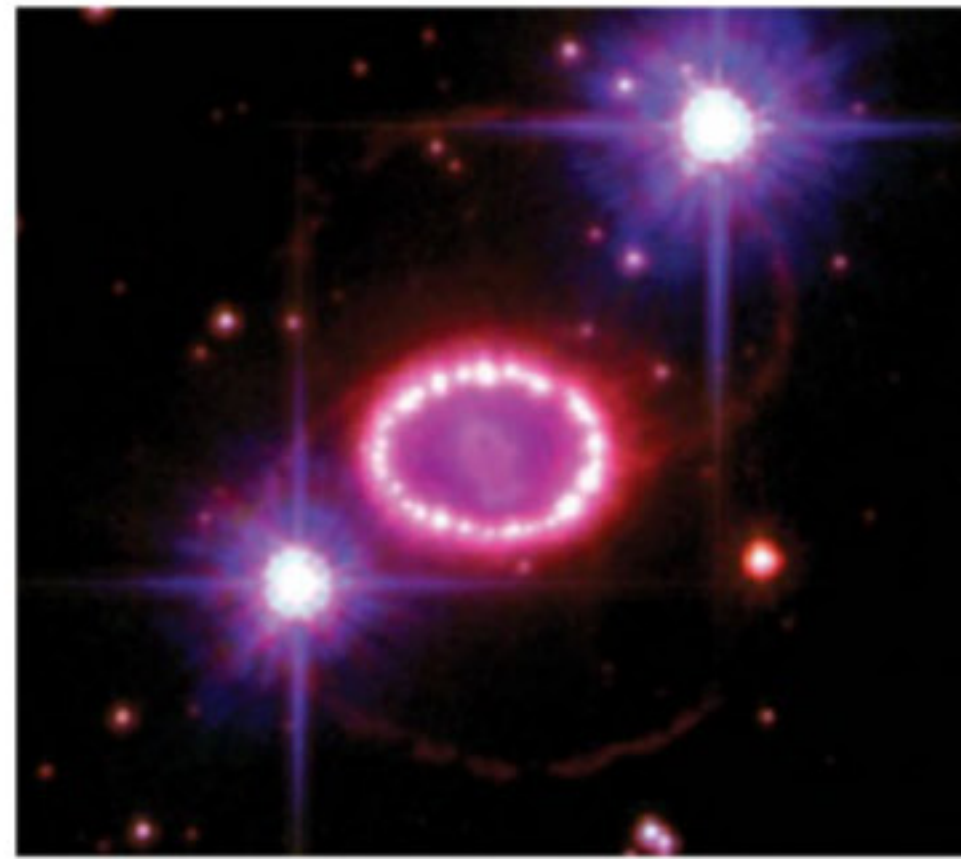
5. Unknown remains

What remains of the core of SN1987A is unknown. Some scientists believe there is a neutron star lying at the centre, others think that it might be a small black hole.



The supernova released such a vast quantity of dust that the centre of the blast zone is entirely obscured. Neutron stars tend to appear as pulsars, releasing streams of X-rays as they spin, but it often takes several hundred years for these signals to appear. At this early stage, Astronomers watch for evidence that a dense star might be pulling in matter from the dust cloud, but so far nothing has been observed.

Some scientists believe there is actually a small black hole at the centre, but this raises difficult questions about how the neutrinos that hit Earth's telescopes could have escaped in the first place. Others hypothesise that it might be a quark star, but the existence of such densely compacted matter has yet to be observed.



Almost 20 years after SN1987A exploded, Hubble's Advanced Camera for Surveys captured this image of the aftermath. The inner ring is glowing under the impact of debris collisions

"Astronomers watch for evidence that a dense star might be pulling in matter from the dust cloud"

Rings of death

SN1987A's unusual history means scientists are only now beginning to piece together the events leading up to its explosive demise

At the time it went supernova, SN1987A was a blue supergiant measuring around 40 times the diameter of the Sun. But just 30,000 years before, it was a red supergiant and a star around five times the mass of the Sun was on a collision path with its core.

As the smaller star circled towards the centre of the supergiant, it whipped up the atmosphere, flattening it into a disc. The spiralling stellar missile heated the gas as

it passed through, causing it to expand outwards. The ejected material settled above and below the disc, forming two distinct rings.

After the collision, the energised core of the merged star spun faster and even more gas was thrown off into space, shrinking the supergiant and forming the third ring. This catastrophic event could well have been the catalyst that initiated the supernova.

"This is a photo the SN1987A remnant taken by the Hubble Space telescope in 2012. We're only beginning to understand what its ring formation is."



By the numbers

20,000

Earth masses of radioactive iron released.

168,000
LIGHT YEARS

The distance from Earth to SN1987A.

10^{57} The number of ultraviolet and X-ray photons released by the explosion.

10 million degrees C
The temperature of the expanding gas shell.

5,000
km/s The expansion rate of the young supernova blast.

200,000
Earth masses of dust created.

Observing SN1987A

Since the first neutrinos from the blast hit Earth in 1987, astronomers have watched this unique supernova evolve

On the night of its explosion, very few telescopes were aimed at SN1987A and just three people are known to have witnessed the first light of the supernova. Two of these men were based at the Las Campanas Observatory in the Chilean Andes, home to two 6.5-metre Magellan telescopes. The other was an amateur astronomer observing the LMC using a 0.3-metre telescope in New Zealand. These were not the first signals to reach the Earth, however.

Two hours before the first light of the supernova was spotted, neutrinos from the blast reached our particle detectors. The Kamiokande II neutrino telescope in Japan is positioned 1,000 metres (3,300 feet) below the ground in the Kamioka mine. On 23 February 1987, the detector was hit by nine neutrinos in the space of two seconds and another three just a few seconds later. Two other telescopes, the IMB detector in Ohio and the Baksan telescope in Russia, also recorded the event, together counting a total of 25 neutrinos.

This might not sound like much compared with the billions upon billions released by a supernova explosion, but neutrinos are almost massless and don't really interact with matter. Most of them race through the Earth without colliding with anything, making their presence extremely hard to detect. The number picked up by the telescopes was huge, and provided the first real evidence of established supernova theory.

At the time of the blast, the most advanced ultraviolet telescope in orbit was the Soviet Astron, which became the first space telescope to image the supernova, but it ceased to function in 1989. Luckily, the Hubble Space Telescope was almost ready for launch, so since 1990 it's been documenting the progress of SN1987A in hundreds of images.

Not only did Hubble reveal the three rings that surround the supernova but, in combination with the Chandra X-ray Observatory, it has been using them to track the progress of the central shockwave, watching as matter from the core of the explosion began to collide with the gas that makes up the ring.

"Around 200 thousand Earths could be formed from the dust"

The heat of the explosion is well documented, but recently infrared telescopes have also begun probing the heart of the supernova. The centre of SN1987A is obscured and the infrared equipment on board the European Space Agency's Herschel Space Observatory revealed an enormous cloud of cold dust, spewed out by the explosion. It's estimated that around 200,000 planets the size of Earth could be formed from the dusty outpourings of SN1987A.

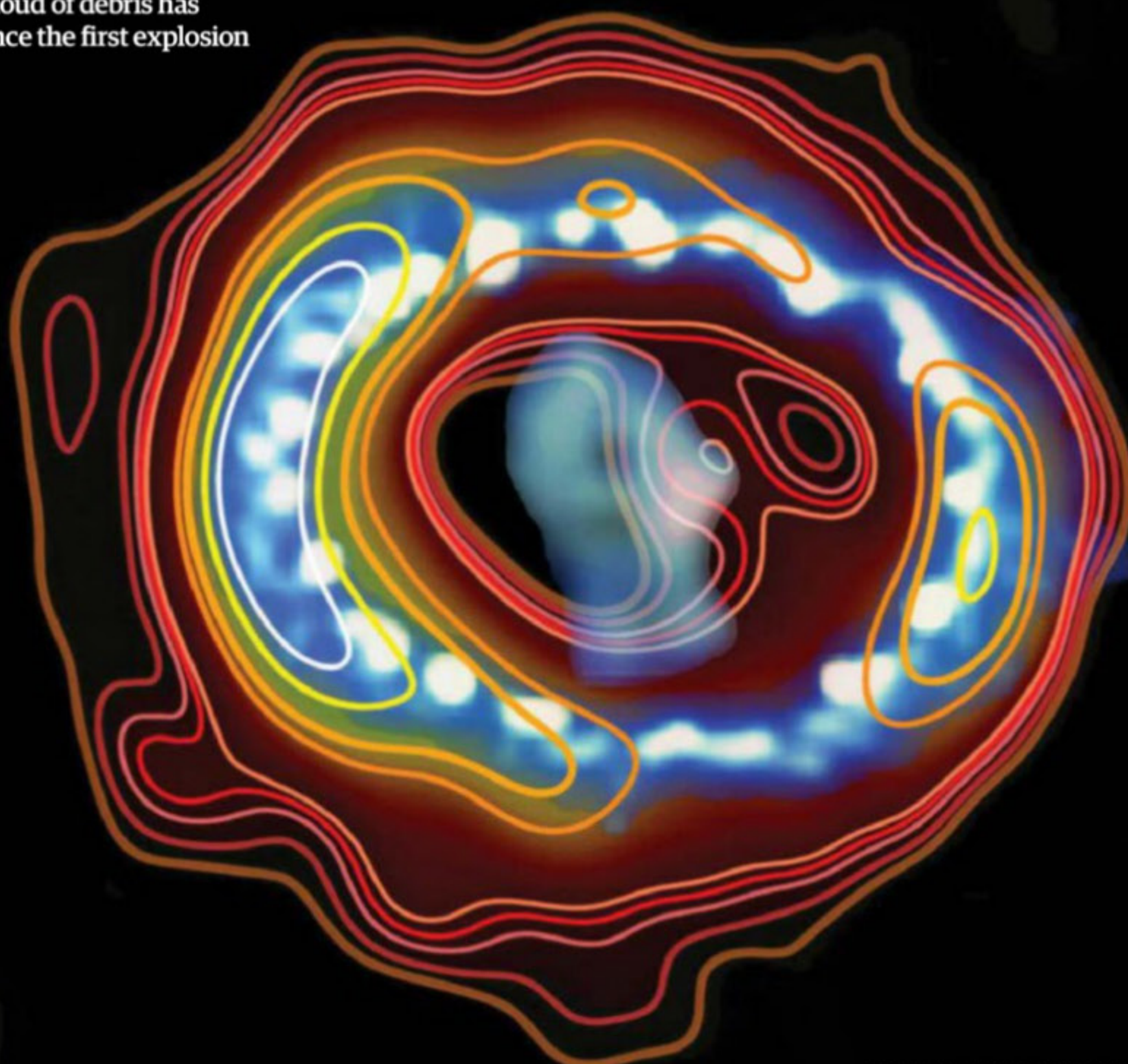
The destruction of the rings around the supernova will be complete within our lifetime, and space telescopes will be able to create an unprecedented timeline of the end of SN1987A's life. As the dust and debris are blown away, advanced instruments like the James Webb Space Telescope will be able to probe the core of the blast, finally identifying the remains of SN1987A. ■

In 1998, Hubble revealed a single bright hotspot on the edge of the inner

By 2000, several more hot gas balls had appeared on the opposite side of the ring

In 2003 almost the entire inner ring was alight as dust and debris from SN1987A tried to pass through

This image reveals the three rings in stunning detail, and shows how much the keyhole-shaped cloud of debris has grown since the first explosion



Ultraviolet telescope

A Soviet satellite, Astron, was launched in March 1983 and was equipped to detect ultraviolet and X-ray radiation. The telescope was only designed to operate for one year, but at the time of SN1987A's discovery four years later, the Astron was still functional.

As the largest ultraviolet space telescope in orbit at the time, it was quickly directed towards the LMC. From 4 to 12 March 1987, Astron captured images of the new supernova, becoming the first space telescope to record the event. By June 1989, the satellite had ceased to function but with the launch of the Hubble Space Telescope in 1990, the view of SN1987A was about to get significantly clearer.

UV telescope

The main instrument on board the Astron was a five-metre (16-foot) long ultraviolet telescope, built as part of a collaboration between the USSR and France.

Main bus

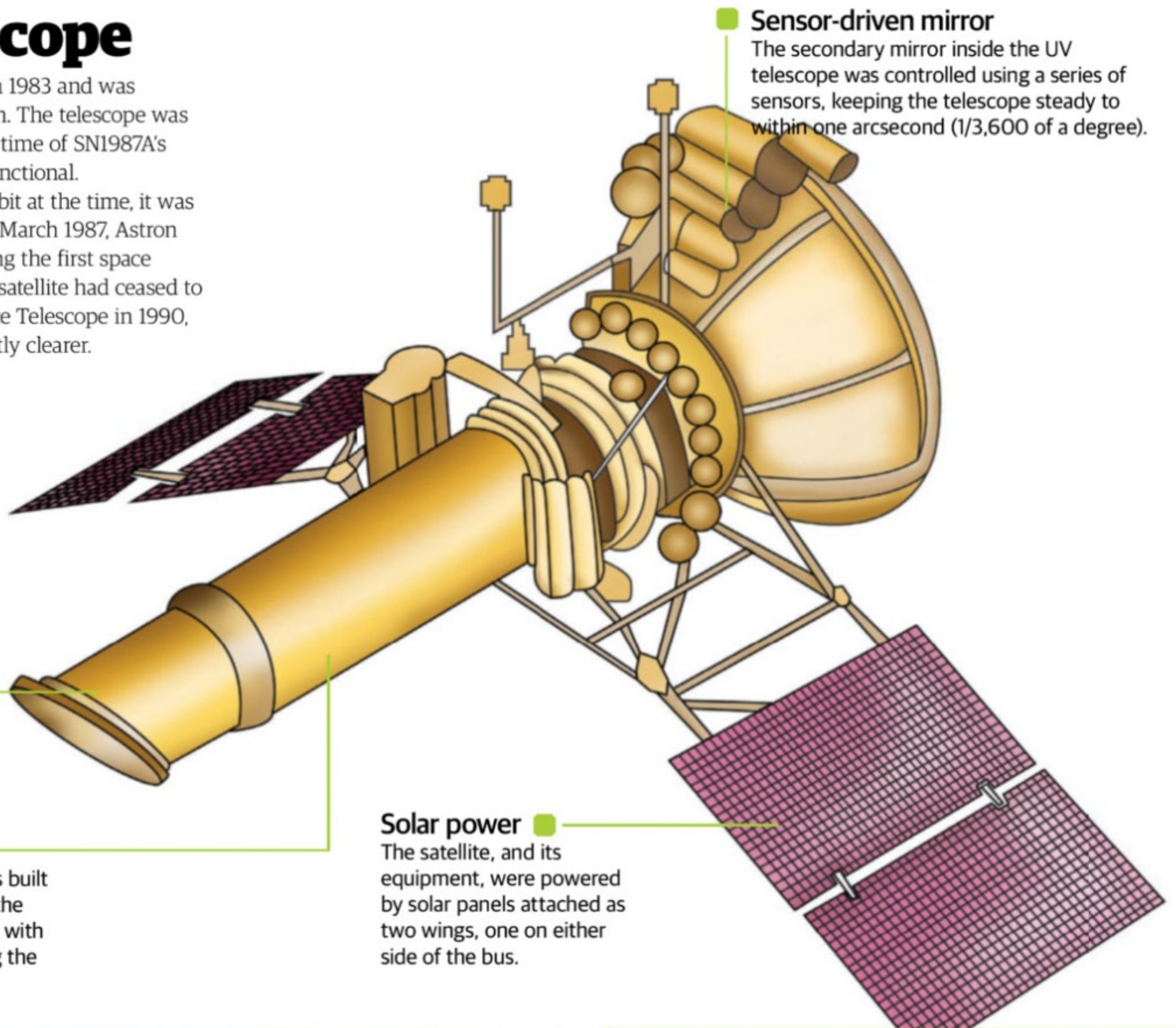
The Astron satellite was built on the same design as the Venus probe, Venera 4, with a central bus containing the scientific payload.

Solar power

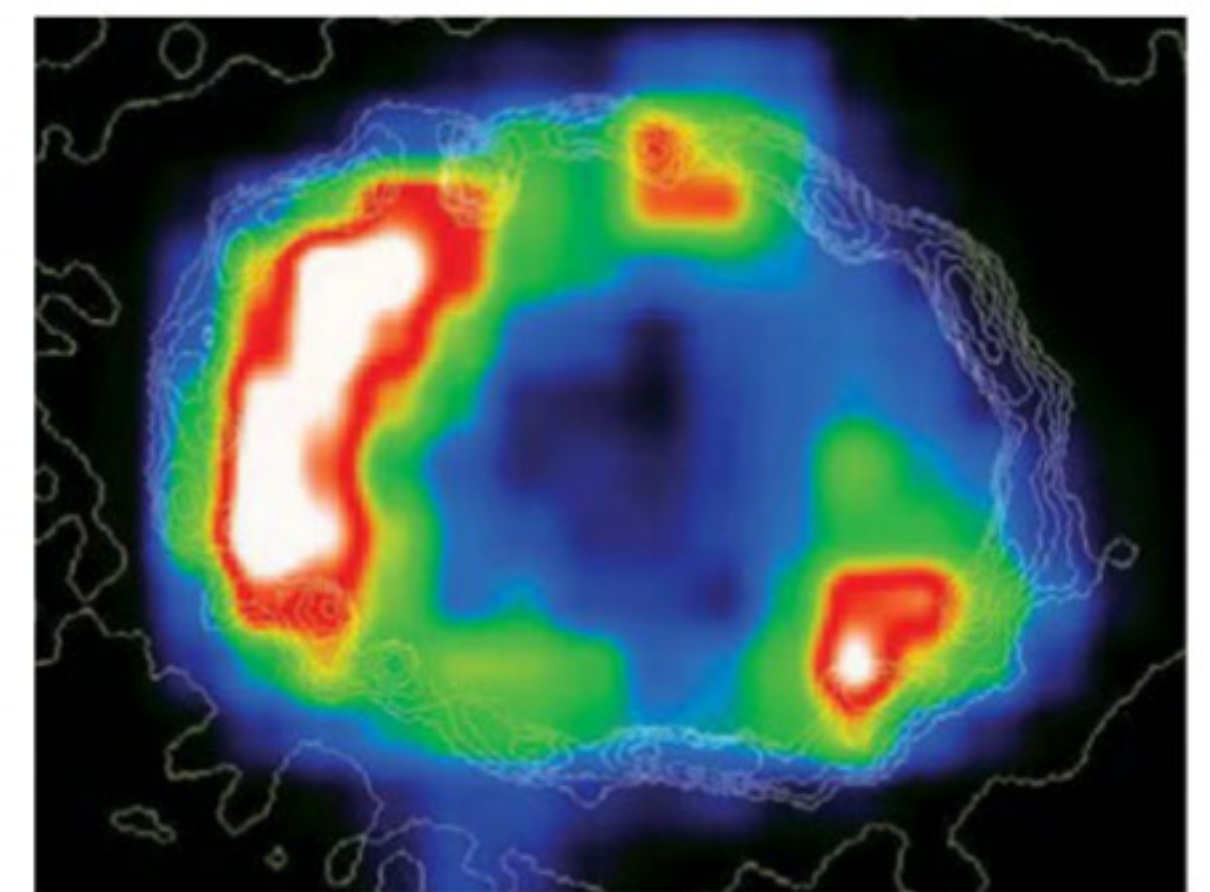
The satellite, and its equipment, were powered by solar panels attached as two wings, one on either side of the bus.

Sensor-driven mirror

The secondary mirror inside the UV telescope was controlled using a series of sensors, keeping the telescope steady to within one arcsecond (1/3,600 of a degree).



Images from Hubble (green) and Chandra (blue) show the collisions occurring on the inner surface of the ring, while radio data from ALMA (red) reveals the cold dust created by the supernova



X-ray vision

Peering within the blast

This X-ray heatmap from the Chandra X-ray observatory shows debris slamming into the inner ring. As the speeding cloud tears through the ten-million-degree Celsius plasma that encircles SN1987A, the shockwave creates X-rays, exciting the gas and causing it to glow. The light of the initial explosion has now faded, replaced by light emitted as the exploded debris cloud tears through the surrounding gas and dust, marking the transition of SN1987A from supernova to supernova remnant - the final display of a deceased star.

What is the shape of space?

How some simple geometry and in-depth astronomy could show us the creation and future of the universe

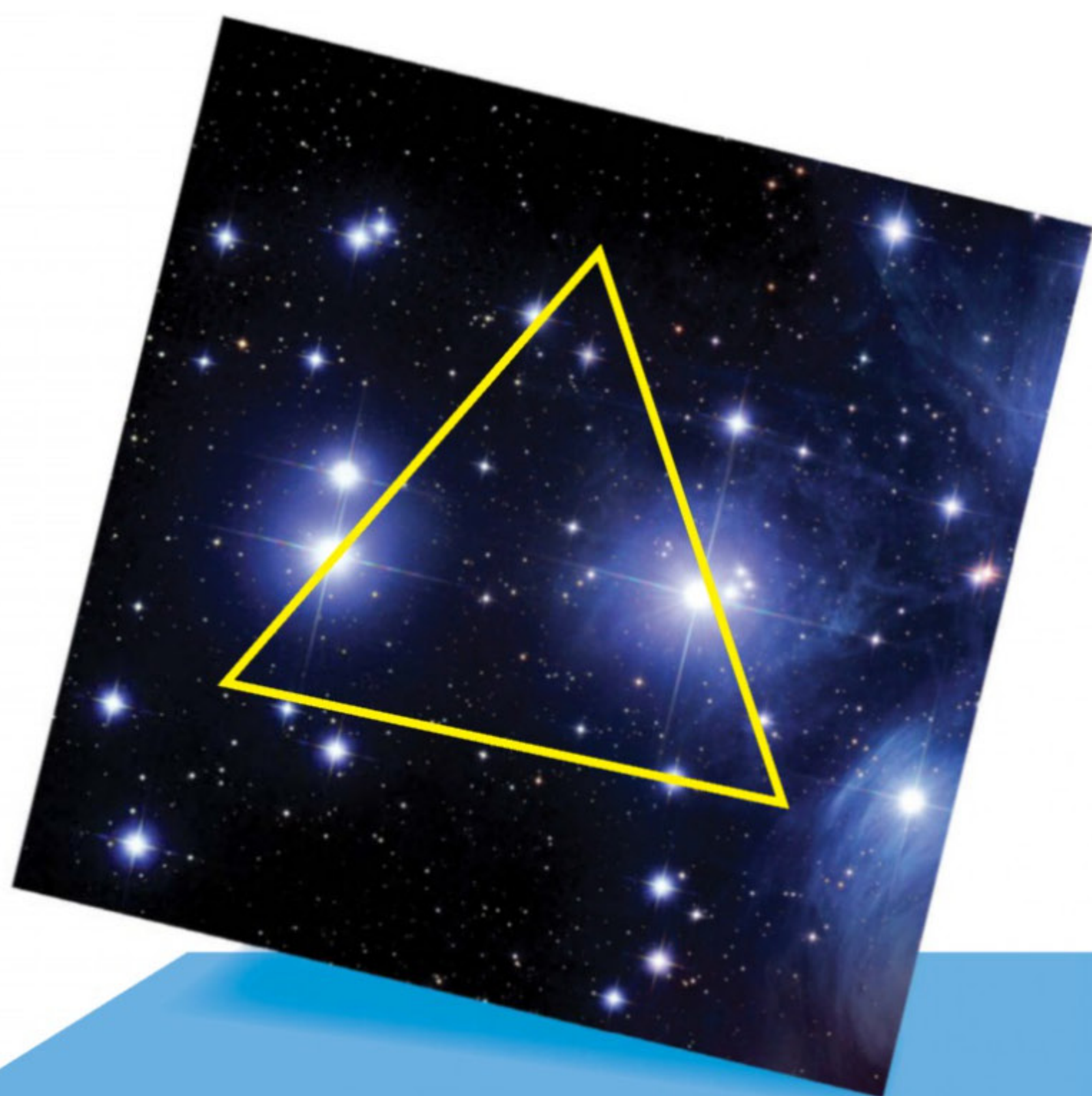
We all grow up learning that the angles of a triangle equal 180 degrees. While that's perfectly true of a triangle drawn on a flat surface, like a piece of paper, it's not the case for all triangles.

Picture a globe and imagine the following. Start from the North Pole and draw a line down to the equator. Then take a 90-degree turn and continue along the equator heading east. Complete the triangle by making another right-angle turn and returning to the North Pole. Having already made two turns of 90 degrees, the triangle's three angles must add up to more than 180 degrees.

The traditional 180-degree rule is part of Euclidean geometry - it doesn't hold true on the surface of a sphere (like the Earth), which is instead governed by a set of rules known as elliptic geometry. Astronomers describe a universe shaped like a sphere as closed. A universe that follows Euclidean geometry is described as flat.

Additionally, it's also possible to imagine a shape where the angles of a triangle add up to less than 180 degrees and in this geometry the shape looks more like a saddle sort of formation. This kind of universe is referred to as open.

So, which of these three possible shapes matches our universe? In order to find out, astronomers observe the cosmic microwave background (CMB), the relic radiation left over from the Big Bang. About 380,000 years after its birth, the universe had expanded and cooled enough for electrons to become bound to atomic nuclei for the first time. This helped disperse a hot atomic fog of particles that had been keeping light trapped. Free to roam, that energy proceeded to pour outwards. It's been travelling across the universe ever since and is what we observe as the CMB.



Flat universe

If the three angles of a triangle add up to exactly 180 degrees, then the universe is said to be flat. Such universes are ruled by Euclidean geometry, which is named after the ancient Greek mathematician Euclid.



Closed universe

Universes where a triangle's angles total more than 180 degrees resemble a sphere and are described as closed. In this case Elliptic geometry must be used instead of Euclidean geometry.

In the billions of years since, the universe continued expanding and this radiation has now cooled to just 2.7 degrees Kelvin above absolute zero (-270.45 degrees Celsius or -454.81 degrees Fahrenheit). It blankets the whole sky and is exceptionally smooth, but crucially not perfectly so.

The CMB has hot and cold spots that differ from the rest of the background by one part in ten thousand. It's by measuring the spacing between these tiny variations that astronomers are able to probe the curvature of the universe, because on its way to us the CMB energy followed the natural shape of space, altering what we observe.

High-precision measurements of the CMB from space telescopes such as NASA's WMAP (the Wilkinson Microwave Anisotropy Probe) and the European Space Agency's Planck have shown the universe to be near enough flat. In this case, its angles all neatly add up to 180 degrees, just like on a sheet of paper.

That's remarkable given the huge range of possibilities. If the universe were open or closed, the sum total of the angles within a triangle could be any one of an enormous range of values. But there's only one value that yields a flat universe: 180 degrees - however improbable, this seems to be the case.

This apparent fine-tuning has been intensely debated by astronomers and physicists for decades. One possible explanation comes in the form of inflation - a slight modification to the original Big Bang theory.

Tied up in the Big Bang is the idea of the ongoing expansion of the universe. Inflation says that the infant universe underwent a period of much faster expansion, growing from smaller than an atom to the size of a grapefruit in just a trillionth of a trillionth of a second. If correct, that would explain our universe's apparent flatness. It could have started out open or closed, but that curvature would have been smoothed out by inflation. ■

"Astronomers observe the cosmic microwave background, the relic radiation left over from the Big Bang"



The Balloon-born Large Aperture Submillimetre Telescope (BLAST) looks at the CMB to see how space formed

Fate of the universe

What will eventually happen to the universe? The answer depends, in part, on its shape

In a closed universe, gravity eventually overcomes the expansion and the universe collapses back in on itself in a scenario called the Big Crunch. In an open universe, there isn't enough gravity to overcome the expansion and the universe continues expanding forever. This is known as the Big Rip. If a universe is flat, which ours appears to be, then the expansion continues but is gradually slowed by gravity.

The picture became more complicated in 1998, however, with the discovery of dark energy. Having already observed that our universe is flat, astronomers expected to find its expansion slowing down. Instead, it was speeding up. Some form of anti-gravity must be pushing the universe apart at an ever-increasing rate. This means our flat universe may actually still end up in the Big Rip.

Open universe

If the three angles of a triangle equal less than 180 degrees, then hyperbolic geometry rules. Universes resulting from these angles are shaped like a saddle and are referred to as open.

Mars lander

Life imitates art as NASA's flying-saucer spaceship design proves successful under test conditions

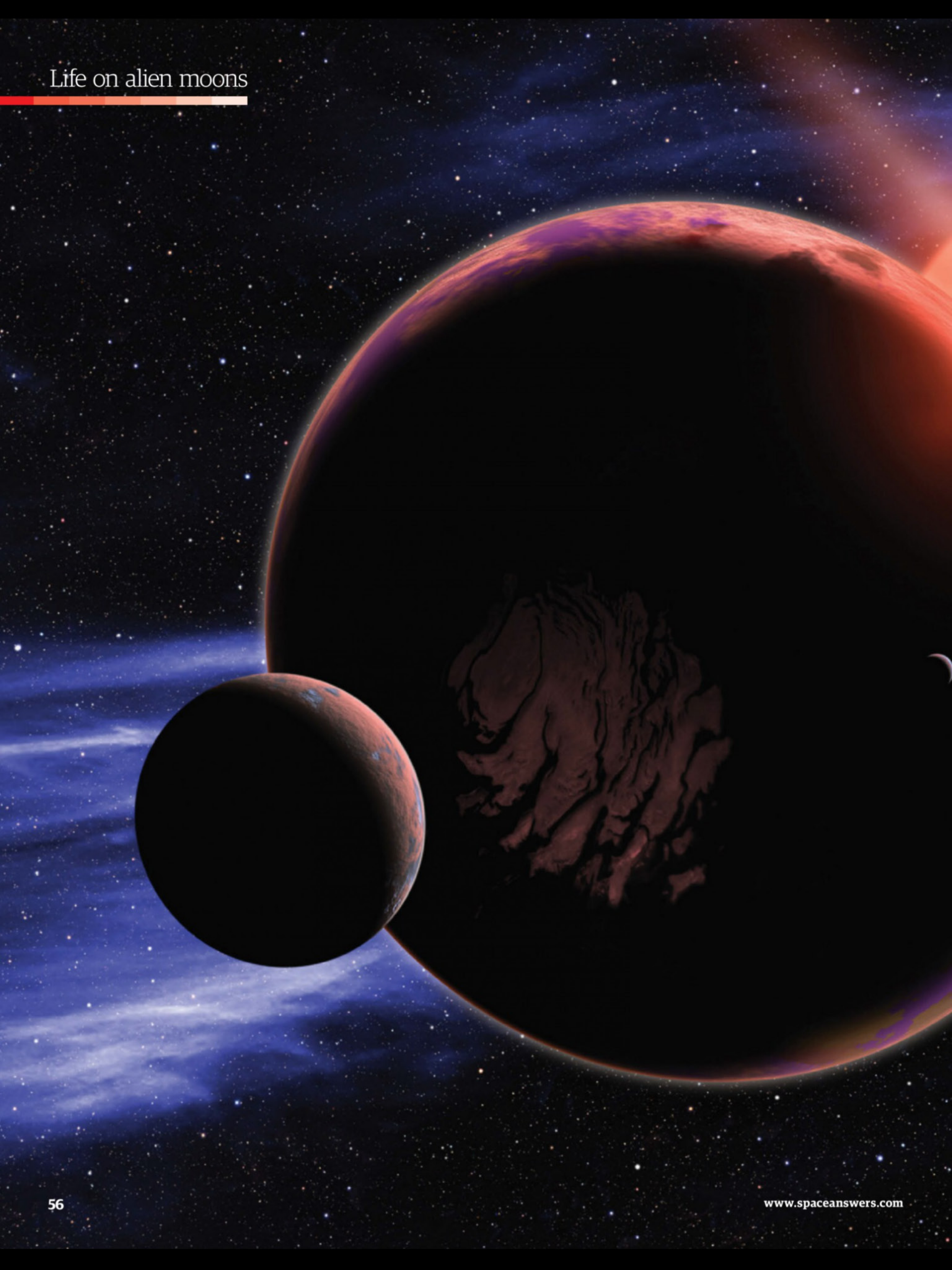
What's this? Perhaps a captured extraterrestrial spacecraft, or a scene from a new science-fiction movie? Actually, this is real technology and it's definitely not of alien origin. NASA's Low-Density Supersonic Decelerator (LDSD) is the space agency's latest flying-saucer-style landing craft project. It incorporates a Supersonic Inflatable Aerodynamic Decelerator (SIAD) - the doughnut-shaped structure that makes up most of the craft in this image.

The LDSD was tested at the end of June 2014, dropped from a high-altitude balloon from an altitude of around 36,500 metres (120,000 feet) over the Pacific Ocean. It took 30 minutes to make splashdown in the ocean below. Although one of the parachutes failed to deploy properly, the SIAD technology performed perfectly, which means there's every chance we could one day see it used to land a real manned Mars mission. ●

Mars lander

NASA's Low-Density Supersonic Decelerator was recovered from the ocean after completing its test with flying colours





Life on ALIEN MOONS



Should we be looking at other planets, or on the satellites orbiting them? Dr. David Kipping talks about life on distant exomoons

Written by Giles Sparrow

Life on alien moons



The moons in our Solar System possess a variety of conditions, but could alien life be thriving under such extremes?

It's now almost 20 years since the first alien planet was discovered in orbit around a Sun-like star. Since then huge advances have led to the discovery of more than a thousand extrasolar planets, or exoplanets, which are now being catalogued. But for those who dream of finding abundant life in the universe, it's been a time of mixed blessings: the vast majority of planets discovered have proved to be gas giants inimical to life, often in orbits so close to their stars that their atmospheres are searing hot.

Fortunately, persistent searches and new techniques have begun to home in on more Earth-like, rocky planets, some of which even lie in the habitable zone where liquid water can exist on the surface. But astronomers are also turning their attention to another possible haven for life - the natural satellites that almost certainly orbit many extrasolar planets, nicknamed exomoons.

Considering the challenges involved in finding exoplanets, discovering their much smaller moons might seem like an impossible task, but that's what first attracted David Kipping of the Harvard-Smithsonian Center for Astrophysics to the challenge. "My interest started more from a dynamical perspective," he explains. "I was interested in the

"If we want to pin down the prospects for life in our galaxy, then we have to include the moons" **Dr David Kipping**

challenge of modelling these things, it's almost like why people want to climb Everest. By 2009 we were just starting to detect lots of transiting exoplanets - NASA's Kepler satellite had been launched with the promise of detecting Earth-sized planets and we naturally wondered whether, if we had a telescope that could find a rocky planet, that maybe it could also find rocky moons."

Kepler was the first satellite designed to use a new planet-hunting technique known as the transit method. Its telescope stared continuously at a packed starfield, watching for tell-tale dips in the brightness of individual stars, caused when orbiting planets transited (passed in front of them), blocking out a small amount of their light. While previous attempts to find exoplanets worked best for giant planets with enough mass to influence their parent star directly, even small, Earth-sized worlds passing in front of

a star's disc should cause a transit effect - it's just a matter of looking in the right place at the right time, with sufficiently sensitive instruments.

Adapting this technique to search for even smaller moons is no easy task, but as leader of the Hunt for Exomoons with Kepler (HEK) project, Dr Kipping has thrown himself into it. "It's a very challenging problem, but we've pushed it from mere speculation into science now. We've developed techniques that should be able to find them, so now we're working on the next challenge, which is trying to actually find them and see whether they're like the moons of our own Solar System, or turn out to be something completely different."

According to our current understanding of the way planets form, at least one type of exomoon should be commonplace: each of our Solar System's giant planets formed with a dense ring of gas, ice and



The closer a planet lies to its star, the less likely it will hold a satellite. Hot Jupiters like HD 189733b are unlikely to have exomoons

debris in orbit around it, which rapidly coalesced to form a system of natural satellites. In some cases (for example Jupiter's four Galilean moons and Saturn's Titan), these moons are the size of small rocky planets in their own right, with complex features such as volcanoes, icy oceans and complicated atmospheres that make them intriguing targets in the search for life in our Solar System. In theory, similar moons should have formed alongside many of the extrasolar gas giants. These could offer potential havens for life.

"Everyone's familiar with that concept from science-fiction books and movies, even if they haven't heard the term exomoon before," continues Dr Kipping. "One interesting reason we might look for them is that we know that gas giant planets are very common and even gas giants within the habitable zone are very common.

"One of the big questions in astronomy right now is identifying the probability of Earth-like planets in the habitable zone," he elaborates. "Kepler's enabled us to quantify that term: there was a recent, very

thorough analysis, which found that two per cent of Sun-like stars have a rocky planet in the habitable zone. Now you can think of that as either a very small or a very big number (because there are so many Sun-like stars in our galaxy), but the same study also found that eight per cent of Sun-like stars have a gas giant in the habitable zone. So if even one quarter of those giants have a rocky moon big enough to have an atmosphere, then there may very well be more habitable moons than planets. Maybe we're the freaks, living on a planet rather than a

Life on alien moons

moon! If we want to pin down the prospects for life in our galaxy, then we have to include the moons."

When it comes to satellites like our own, however, we can't be so confident, at least not yet. Earth's Moon formed in the aftermath of a giant interplanetary collision that shook the young Earth to its core, but as Dr Kipping says: "We have no idea whether that giant impact that created our Moon was a freak event, or the kind of thing that happens all the time - and with only one example in our Solar System, we just can't tell."

Dr Kipping points out another important reason to look for moons that are just like our own: "I call it extrinsic habitability. The presence of our Moon may have been beneficial to the emergence of life on Earth: it stabilises the axial tilt and climate and causes tides that mix the oceans and create tidal

pools where life itself may have started. If we find an Earth twin, one of the first questions we'll ask is 'does it have a Moon twin?', because that's been so influential on our own planet."

The HEK Project sifts data from Kepler looking for three different effects, each of which can reveal unique information about potential exomoons. Identifying periodic smaller transits caused by a satellite associated with a larger exoplanet is the most obvious of these (though it's a challenge that still stretches the sensitivity of Kepler's instruments). "Very simply, if you have a planet orbiting a star with the right alignment to our line of sight, you get a transit and if it has a moon, that will usually either appear to be leading or trailing behind the planet, so you will see an additional dip in the star's brightness when the moon blocks out light," explains Dr

Kipping. "If you look over many orbits, then you'll see the dip from the moon at a different point in relation to the dip from the planet every time. It's not random - it's dictated by Kepler's laws of planetary motion. So, we basically model that in a computer, simulating a mini Solar System to see how it evolves and whether the little dips in the data can be explained by a moon, or maybe something else such as another exoplanet, or activity on the star itself."

The other effects are more subtle - changes in the timing of the exoplanet's own transit and differences in its duration, both caused by the planet wobbling under the influence of its moon. Dr Kipping illustrates this with an example that's much closer at hand: "If a distant alien were looking at Earth transiting the Sun, you might think it would see transit at identical intervals of about 365.256 days

The alien moon hunter

NASA's Kepler Space Telescope provided a wealth of raw data for experts searching for exomoons as it stared continuously towards a field of stars in the northern sky over four years, looking for tell-tale fluctuations in their brightness.

Telescope

Kepler's 1.4-metre primary mirror is the largest ever placed beyond Earth orbit - the satellite orbits the Sun in order to avoid gravitational wobbles caused by our planet.

Thruster modules

These miniature rocket thrusters used jets of gas to adjust Kepler's position in space.

Reaction wheels

Spinning these four wheels provided fine guidance for Kepler's orientation - the failure of two wheels by May 2013 brought an end to Kepler's primary mission.

Sunshade

A large shade protects the camera from direct or reflected sunlight, while radiators on the spacecraft's dark side shed excess heat.

Solar arrays

Solar panels wrapped around one side provide power to Kepler. In 2014, scientists and engineers developed an ingenious way of using them to control the spacecraft's orientation, opening the way for an extended K2 mission.

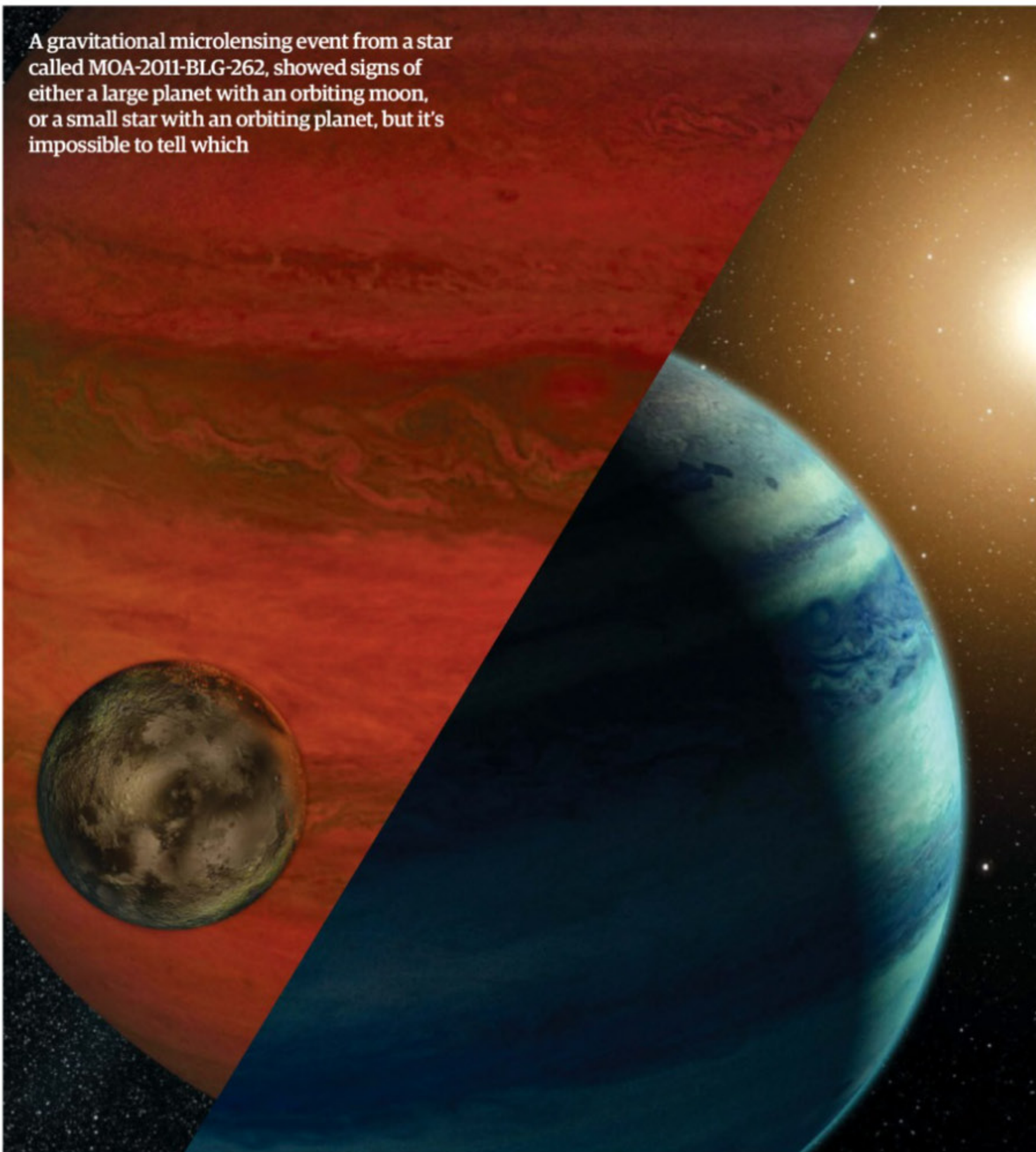
Photometer

Kepler's sole instrument is a photometer - a specialised CCD camera capable of monitoring the brightness of some 145,000 stars simultaneously and looking for tiny variations.

Star trackers

These small cameras help Kepler find its orientation in space.

A gravitational microlensing event from a star called MOA-2011-BLG-262, showed signs of either a large planet with an orbiting moon, or a small star with an orbiting planet, but it's impossible to tell which



“If you know the mass and size you can get the density – that tells you roughly what the moon is made of” **Dr David Kipping**

[Earth's official orbital period around the Sun], but in fact that transit could happen five minutes earlier or later. That's because the thing that actually orbits the Sun like clockwork is the centre of mass of the Earth-Moon system. The Earth and Moon are both orbiting around that point in space and although the centre of mass is deep inside the Earth [about 1,700 kilometres or 1,056 miles below the surface], Earth's wobble is enough to create variations of a few minutes.

“What's more, sometimes the planet seems to move across the star a bit quicker or a bit slower, because the tug of the Moon is causing its velocity through space to vary,” Dr Kipping continues. “It's a bit like a pendulum: the duration effect is at its maximum when the timing effect is at its minimum and vice versa.”

Putting all this information together could, in theory, lead to some impressive and revealing results: “Kepler can just about detect these kinds of timing

variations, so you can then get the mass of the moon from the wobble of the planet and the size of the moon from the transit dip itself. If you know the mass and size you can get the density – that tells you roughly what the moon is made of. If it's an icy moon you get a density of maybe one or two grams per cubic centimetre, whereas if it's rocky then you're looking at about twice that.”

In practise, of course, sifting the enormous amounts of data collected by Kepler between its launch in 2009 and eventual breakdown in 2013 is an exacting task. Based on its criteria of measuring over three transit events in front of a particular star, Kepler detected at least 4,000 planetary candidates.

Unfortunately, most of these planets can be dismissed immediately as unlikely to have orbiting moons. The transit technique is naturally biased towards planets that are very close to their stars and many exoplanets orbit so close that their star's

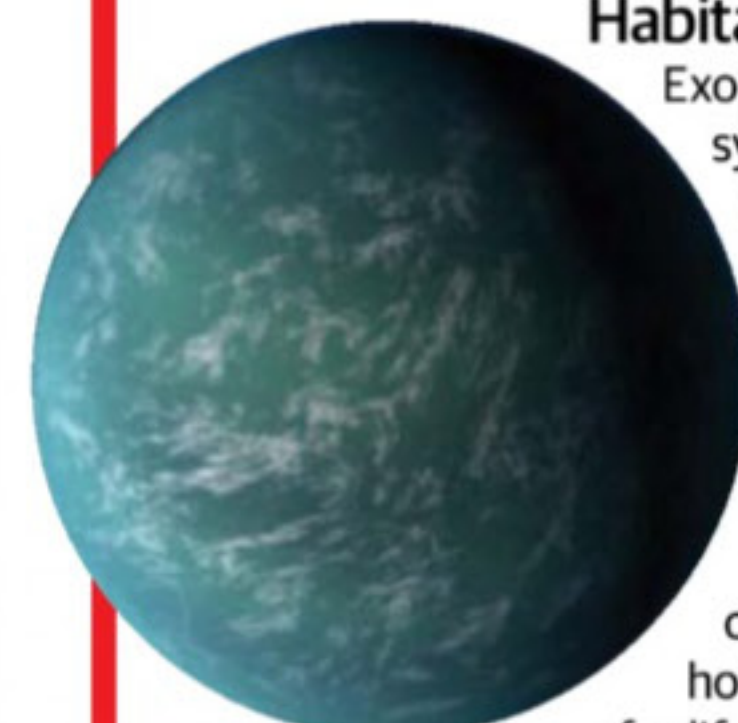
The moon family portrait

Researchers group hypothetical exomoons into a number of different categories depending on their potential for life – hot, habitable, snowball and transient



Hot exomoons

Too close to a star and an exomoon may have an average temperature above the boiling point of water, making it highly unsuitable for any form of life.



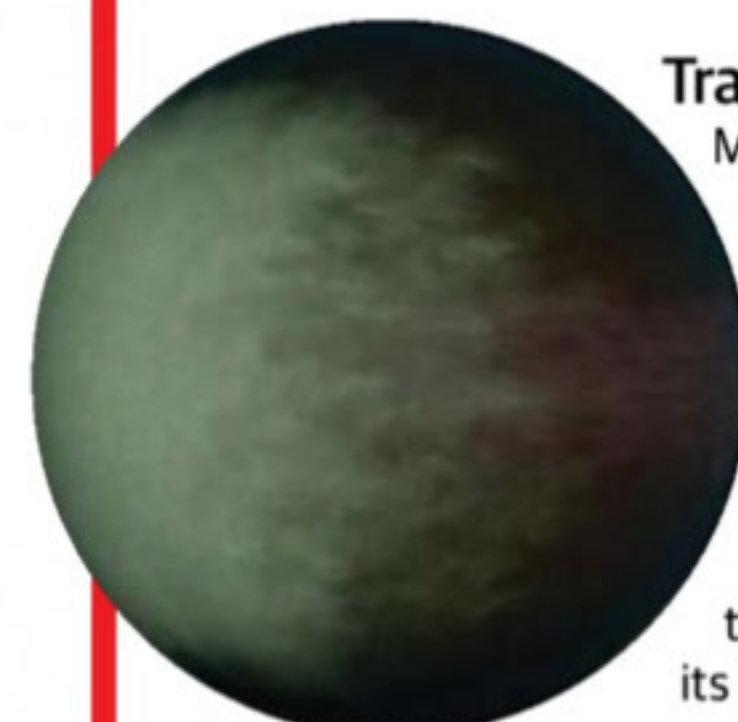
Habitable exomoons

Exoplanets orbiting in a system's habitable zone (where liquid water can persist on a planet's surface) still need sufficient gravity to trap an atmosphere that regulates their temperature. If these conditions are met, however, the prospects for life are promising.



Snowball exomoons

Moons formed in the outer reaches of an alien solar system are likely to be dominated by ice. They will remain deep-frozen unless heated by tides from their parent planet – again these are unlikely to be habitats for life.



Transient exomoons

Moons of planets with elliptical orbits might be habitable for most of their planet's year, but can experience hot or snowball periods as they venture too close to their star, or too far from its life-giving heat.

How to find an exomoon

Locating a companion to a distant exoplanet can be tricky, but astronomers have a few tricks up their sleeves

Radial velocity method

The most successful method for hunting extrasolar planets involves detecting minute changes in the wavelength of light from stars as they move towards or away from Earth. If these changes are periodic, they may be caused by the star wobbling under the influence of an orbiting high-mass planet. However, the influence of a moon on this effect is negligible since the moon is likely to pull the star in almost exactly the same direction as its parent planet. The ability to directly measure the light from exoplanets in order to detect their own wobbles is sadly beyond the reach of current technology.

Transit timing effect

Even if an exomoon cannot be seen directly, it may be detectable through its influence on its parent planet. As the planet and moon both circle around their common centre of gravity, the planet will sometimes run ahead of this point as seen from Earth and sometimes fall behind it.

This can affect the time at which a predicted transit begins, perhaps even by a few minutes. The effect is at its greatest with moons that are quite massive compared with their planets (systems similar to the Earth and Moon) - in contrast, gas giant planets are so massive that even huge satellites would produce only a tiny timing effect.

Host star

The star orbits very close to the system's centre of mass, wobbling slightly around it.

Centre of mass

All the objects in a Solar System orbit around the same overall centre of mass.

Extrasolar planet

Planets have very low masses compared with their stars, and orbit far from the centre of mass.

Stretched light

When the star's regular wobble carries it away from us, wavelengths of light reaching Earth are redshifted.

Compressed light

When the wobble carries the star towards us, wavelengths of light approaching Earth appear bluer.

Microlensing

This technique is almost the opposite of the transit effect - it involves looking for a brief brightening in a star's light as an object (such as a planet orbiting another star) passing in front of it bends and boosts its light through the affect of gravitational lensing.

In theory this method can detect less-massive objects than the traditional transit method, as well as spot differences in the lensing effect caused by the presence of exomoons. However, such events require precise alignments and tend to be one-offs - analysis may produce candidate exoplanets and exomoons, but it's almost impossible to confirm their existence with follow-up observations.

Transit method

The transit technique looks for dips in a star's brightness as other objects pass in front of it - periodic and sudden changes in its light output can be linked to orbiting exoplanets and their moons.

The method is biased towards detecting larger objects in orbits close to their stars, but not as badly as the radial velocity technique is biased towards high-mass planets. Looking for small additional dips associated with planetary transits is the obvious way to detect exomoons, but it requires close study and a satellite telescope above atmospheric light absorption.

Observer



Planet

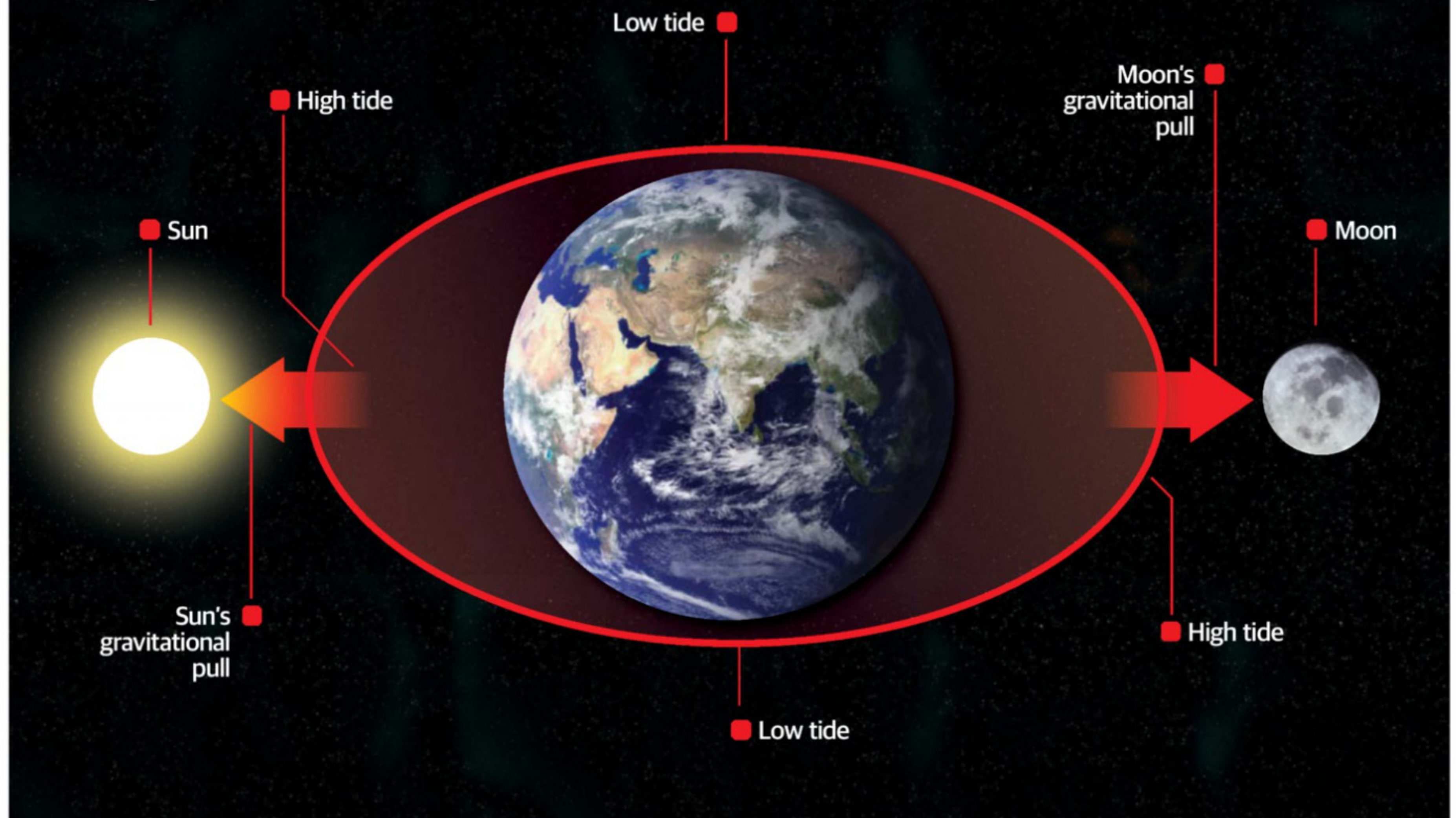


Source star



Lens star

The presence of Earth's Moon creates shifting tidal zones that may have been vital to the origin of life



"I can't believe nature doesn't build moons frequently - it has a much greater imagination than ourselves" Dr David Kipping

gravity would simply rip any hypothetical moons out of orbit. In fact, only about ten per cent of Kepler candidates orbit far enough from their stars to potentially hold satellites.

"These days, it might feel like Kepler planets are a dime a dozen, but the subset of these long-period planets are very special to us and very precious," Dr Kipping explains. "We believe it's worth studying each one of these with a fine tooth comb to look for moons because, whether we find them or not - if they're common or rare - the answer is going to be one of the most important in modern astronomy."

So, how is progress going? "We've studied about 20 of them so far, and at the moment we're doing about 40 per year, so by the end of this year we'll publish the results for about that many. I'm not going to give the game away, but our aim is to look through at least the 100 or 200 best candidates and once we've looked at that many, we can say something in statistical terms about how common or rare big moons are in the universe."

However, things aren't entirely straightforward, since the methods used by the HEK team rely on a relatively massive moon capable of influencing

its parent planet. "In terms of sensitivity, the data is good enough for us to detect Earth-like moons or smaller in about half the cases we're studying," admits Kipping. "So after looking at those 200 or so exoplanets we should have a much better idea of how frequently moons form by the kind of giant impact process that created our own Moon."

Ironically, the most-common exomoons, those around gas giants, are also the hardest to conclusively detect. Though they might be massive in their own right, such moons are dwarfed by the mass of their planets and have only the tiniest affect on the timing or duration of transit events. "They're still quite big of course, so it might be possible to see just the transit signature, but you wouldn't get the timing effects or the mass," points out Dr Kipping. "Without that I think it would be very difficult to prove you had definitely found a genuine exomoon."

Dr Kipping remains hopeful for the prospect of finding Earth-like exoplanets and their moons: "I'm still very optimistic we'll find them in the next year or two. I can't believe nature doesn't build moons frequently - it has a much greater imagination than ourselves, as it's proved this over and over again." ■



The Kepler Space Telescope is equipped with a specialised CCD camera



The search for alien life on exomoons

Assuming that exomoons are found, the big question is whether they would have the potential to be habitable. Dr René Heller has carried out eye-opening work on the constraints that govern the habitability of these worlds

Could you tell us what first got you interested in searching for exomoons?

What I find interesting about moons is that they are so much more abundant than planets, at least in the Solar System. They are so diverse! Some of them have atmospheres, some have volcanoes, some have internal magnetic fields, some have subsurface oceans - one of them [Titan] even has clouds and rain. This suggests an enormous population of moons around the known extrasolar planets, some of which might fundamentally challenge our picture of planet and moon formation. I consider it almost natural that some of these strange moons have habitable environments.

You're mainly researching the properties of moons around gas giants?

Yes, so far I've mostly been interested in big moons around Jupiter-like planets. Theories suggest that the biggest planets have the biggest moons - the king of the moons in our own Solar System, Ganymede, orbits Jupiter and some extrasolar planets are even more-massive than Jupiter, so they might have moons as massive as Mars. If such a system orbited a Sun-like star at an Earth-like distance, the moon - though not the gas giant planet - could be habitable. Isn't that an absolutely fascinating possibility?

These kinds of moon might be more-common than worlds like our own Moon, but aren't they much more difficult to detect than the planets they orbit?

Using the standard dynamical strategies for moon-detection, moons around very massive planets are indeed hard to find - but if we consider the direct transit signature of the moon itself, then the moons around giant planets are actually very promising targets. A moon's own transit signal depends only on its diameter relative to the star - the larger it is, the larger the dip in the transit light curve. With the biggest planets hosting the largest moons, the

search for a moon's own transit dip works actually best for moons around giant planets.

So what factors would influence the habitability of an exomoon?

Talking about the possibility of liquid water on the surface, rather than under a frozen ice sheet, a moon needs to be at least as massive as Mars in order to have a gravitational field that is strong enough to retain a substantial atmosphere for billions of years. An atmosphere is needed to enable moderate temperature variations between night and day, as well as to sustain some kind weathering and global water transport. Since atmospheres of moons cannot possibly be detected directly in the near future, the size and mass of a moon are fundamental to assess its habitability to begin with. Intriguingly, all the available exomoon-detection methods work best for bigger moons, so they are actually biased towards potentially habitable worlds.

Are there any other constraints to the areas you have to search within?

Beyond mass and size, stellar illumination plays a key role. Too close to the star and the moon might be in a runaway greenhouse state, similar to Venus, or may lose its atmosphere entirely due to thermal escape. Too far away and the moon's atmosphere will freeze out, similar to what has happened on Mars. So the stellar distance of the planet-moon

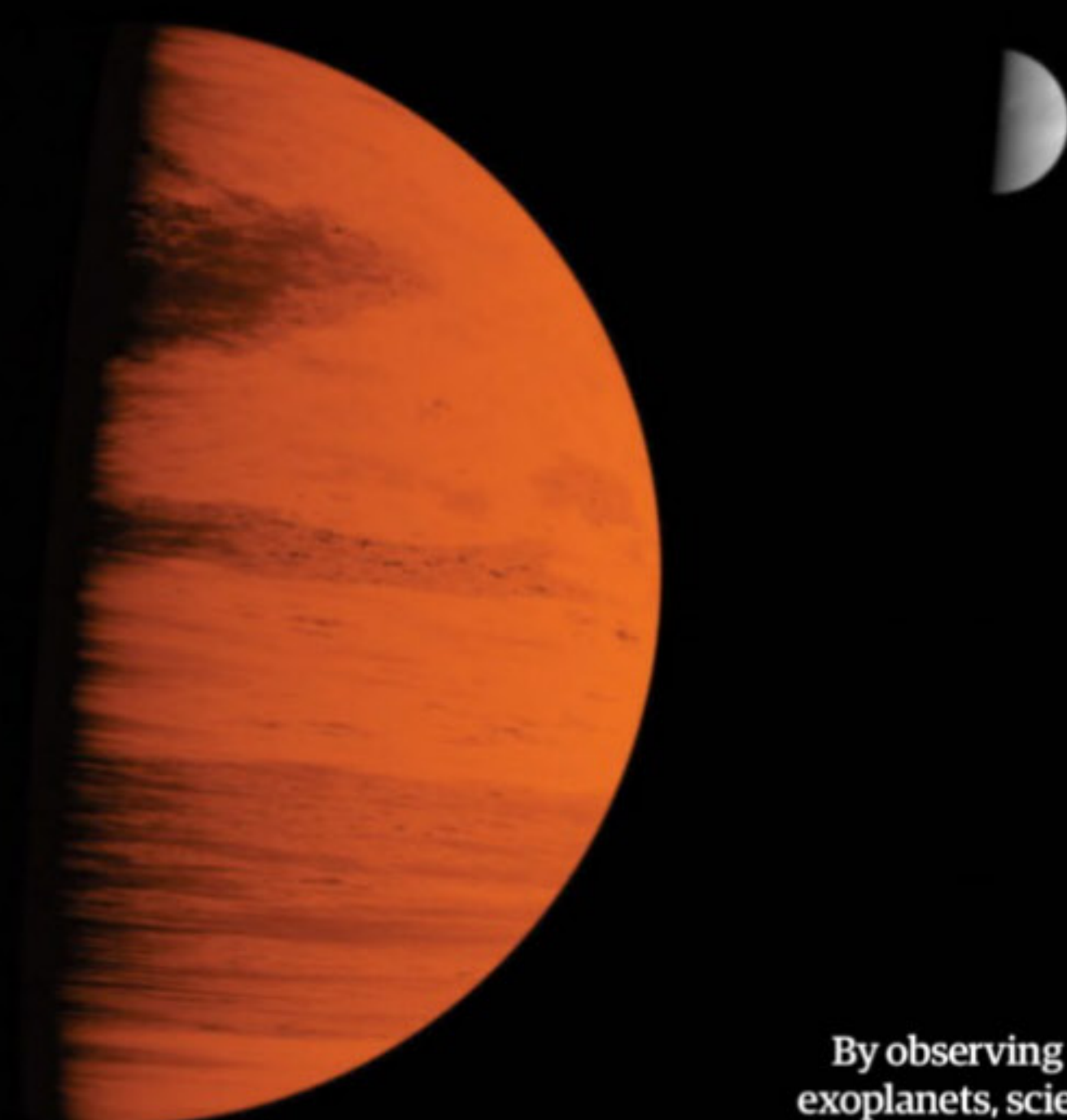
system must be within a certain range, maybe in the so-called stellar habitable zone. But on top of that, a moon receives illumination from the planet - reflected starlight as well as the planet's own thermal emissions. What makes things even more interesting is the internal heat reservoir generated in the moon by tidal dissipation. If a moon isn't on a perfectly circular orbit, maybe because there are other moons causing gravitational perturbations, then the varying gravitational pull of the planet on the moon will knead the moon, heating it up through internal friction. The closer a moon to its planet, the stronger this tidal heating.

So just as in our Solar System, that could create a potentially habitable environment outside of the normal habitable zone. What chance do you think we have of proving such worlds exist?

If an exomoon can be detected, then its mass, its distance to the planet and maybe even its radius would be known by means of the methods that we use to search for them. A moon's mass and radius combined would give us an idea about its average density, which might enable us to classify it as a rocky, a water-rich, or an icy moon. So depending on the data quality, the basic moon characteristics, as well as the basic physical values of the planet and the star should come alongside the detection. These values alone should give us a reasonable evaluation of the possibility of a moon being habitable - they might be [found] in data from Kepler.

But answering the question of [whether or not] a moon is actually inhabited by some form of life would certainly be a task for the next generation of astronomers and astrobiologists, who would need to measure whether the moon has an atmosphere and liquid surface water. Currently available instruments wouldn't permit such studies, but they're possible in principle. Humanity just needs to decide to perform such investigations and then we need a bunch of very capable engineers.

By observing the very largest exoplanets, scientists expect to find the very largest exomoons, which could be habitable



Six-star sunrise

How do these crowded stellar systems form and what are their orbits like?

Looking up into the night sky we can see billions of stars, conditions permitting. However, what has only become apparent as telescopes have increased in capability is that up to half the stars we see could be multiple-star systems. In these, two, three or even six stars orbit one another. The easiest multiple systems to identify are those where a telescope lets us resolve what appears to be a single star into two or more points of light. However, we can now tell that even more stars are actually doubles, even if they are too close for us to separate. We can tell this because of how the starlight changes as the pair rotate around each other.

Stars and planets form as clouds of interstellar gas and dust clump together through the gravitational attraction of the particles. As the clumps develop, they start to attract more and more of their surrounding matter, which collapses the cloud in towards its centre. The random collisions of the particles set the cloud spinning and the spin turns the whole lot into a disc shape.

In our Solar System, one big clump in the middle of our cloudy disc became the Sun, while several smaller eddies became the planets, moons and everything else orbiting it. In a multiple-star system two or more big clumps end up forming stars, all moving around their common centre. If two stars are the same mass, they will orbit around a central point (the barycentre) between the two. If one is more massive, then this centre of the orbit will be closer to the larger one.

The distances between the stars must be just right for these multiple systems to remain stable and form hierarchies. Collections of newly formed multiples have been found in groups called trapezia, named after the multiple-star system Trapezium in

the Orion nebula. These trapezia have chaotic orbits that have not yet settled down, but ultimately they will find a stable arrangement. Here the group can be separated into several smaller binary subgroups, and astronomers use a mobile-type tree diagram to illustrate their orbital arrangements.

A triple system, for example, will settle into a pair that rotates around each other. The third star will orbit the other two at a distance, but as if they were one. The relative sizes of the orbits are key and we now know that a suitably packed system makes all the difference for the potential planets forming too.

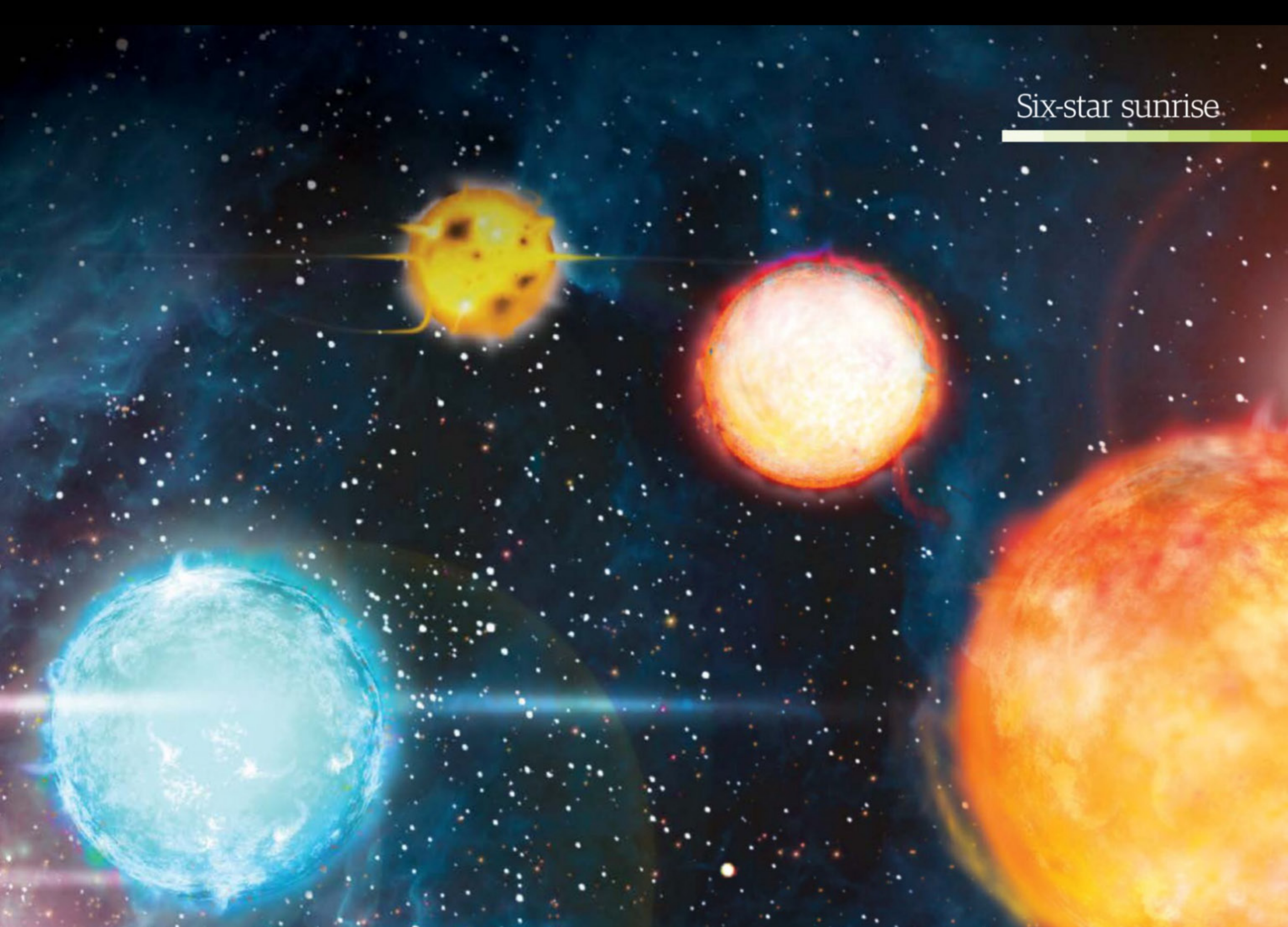
We are living in one of the most exciting times for astronomy. Only 20 years ago we weren't even sure that there were planets around other stars, that our Solar System could have been a universal freak. But since then over 1,700 exoplanets have been confirmed, so we can almost start drawing up an atlas of planetary systems.

Our detection methods are indirect - we look for the distinct wobble or dimming of a star caused by an orbiting planet, so the first discoveries were of huge, hot planets. But the sensitivity of our detectors is getting much better and astronomers have now confirmed the existence of smaller, cooler star systems more like our own. More unexpected was

the recent discovery of a pair of planets orbiting a binary star Kepler-47, which confirms the possibility of a multiple-star sunset on other worlds. This brings to mind those two-star desert scenes on Tatooine, in the *Star Wars* films.

Again, like the existence of exoplanets themselves, researchers were unsure if planets could exist around binary stars without being flung away or pulled apart, but the Kepler-47 system has at least two planets orbiting two stars. One is the size of the Sun and the other about a third of the size, eclipsing each other (from our perspective on Earth) in only 7.5 days. This close relationship means that the planets can orbit around the binary pair.

The larger of the planets is orbiting in the habitable zone and though it's too big to be Earth-like, it could have Earth-like moons, similar to *Avatar's* Pandora. The discovery of multiple planets orbiting in a multiple-star system has tremendous implications for the number of planets in the galaxy and therefore the potential for life. ■



Multiple-star systems

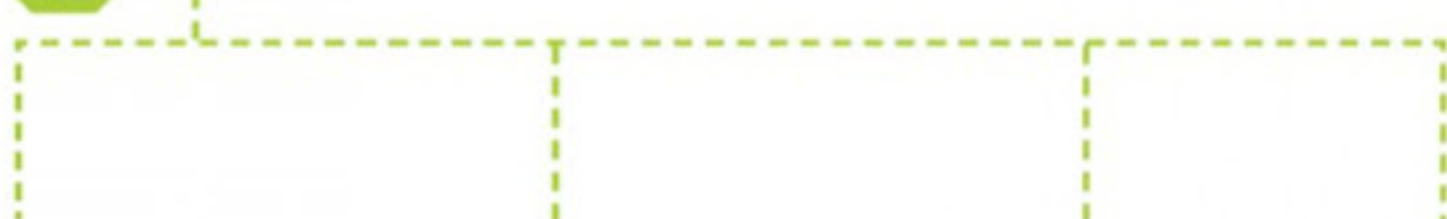
Stable multiple-star systems tend to orbit in groups of two, called hierarchies. These can be mixed up into more-complicated groups. A jumble of stars orbiting together would orbit like (a) and called a multiplex.

The second type (b) is called simplex and shows a basic pair - a binary, (c) and (d) show a triple and a quadruple system. These are said to have a hierarchy of two, because there are two levels. System (e) shows

a quadruple star with three levels. Two stars are in a binary with another orbiting them and a fourth going round the whole group. Planets can similarly orbit an individual star or the whole group, which would affect

the skies the surface. On Kepler-47 you would see two stars; whereas our nearest exoplanet, Alpha Centauri Bb, orbits one star in a triple system. Here you would see one main star, but also two others in the sky.

A



Three for the price of one

Our closest group of stars, the Alpha Centauri system, appears as the third-brightest single star in the sky. It's actually three stars: a Sun-like star, a star that's little smaller and more orange, and a small red dwarf orbiting the other two.

B



C



D



E



Trapezia

Seen in newly formed groups of stars, trapezia are systems that haven't found a stable condition yet. The stars move chaotically around one another and may well expel some members while others could merge to find that stability.

F



The new Hubble Space Telescope

Professor Martin Barstow on his plans for a new and ambitious mission, ATLAST, which is set to answer one of the biggest questions of all time

Interviewed by Gemma Lavender



INTERVIEW BIOS

Martin Barstow

A professor of both Astrophysics and Space Science at the University of Leicester, Barstow is also president of the Royal Astronomical Society. A chartered physicist, he's also head and pro-vice-chancellor of Leicester's College of Science and Engineering.

What's most enjoyable about being president of the Royal Astronomical Society (RAS)?

I've only been really doing it since May, so actually being here at NAM [the National Astronomy Meeting 2014] has been the most enjoyable part so far, interacting with all of the people who have come...

You might not be aware, but I was actually elected in a competition [which hasn't happened] in about 160 years. It's always been quite difficult to get more than one person to stand for president and in fact it's usually been the case where the council has had to go and twist a few arms to get anybody to be president. I think having an election through people with a real competition enables the opportunity to state and stand for what you have to do as president. It's really an amazing breakthrough, I think, for democracy and society. There are things that I want to do - I want to improve the diversity in the RAS.

A new mission has been proposed - the Advanced Technology Large-Aperture Space Telescope (ATLAST). How did you come to get so heavily involved in it?

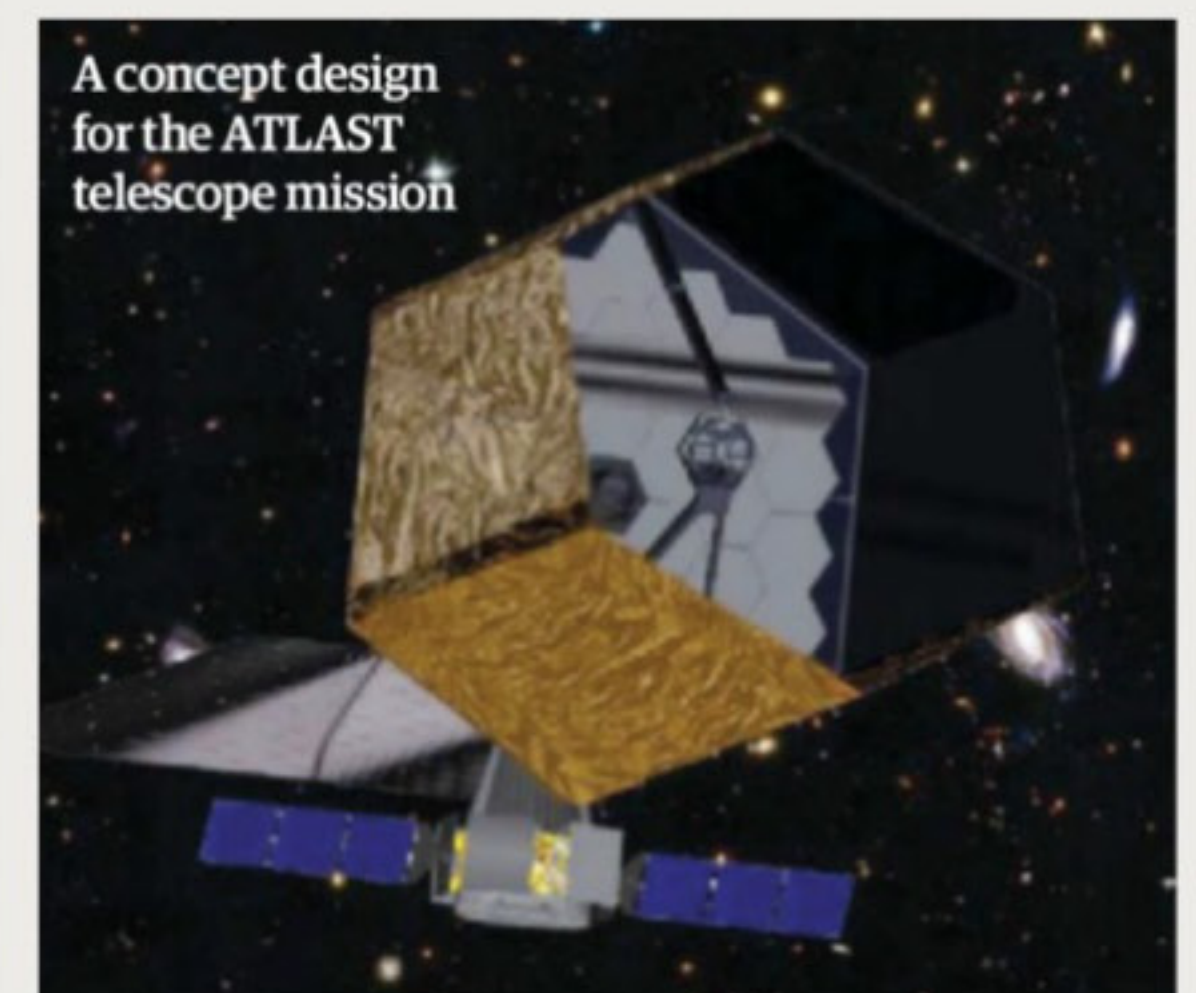
I've been involved in Hubble for a long time. It's been a workhorse of my personal research and because of that, over the years, I got drawn into big parts of Hubble committees and things like that - particularly oversight committees. One of the most exciting jobs I've ever had was being involved in the last servicing mission, where I was on a committee that was overseeing things like what we do in the space walks, [or deciding] which are our major instrument priorities if we don't have as many space walks as we want. So I got deeply involved in the programme.

As I have become more involved in Hubble and have seen that its life is limited, as inevitably any space mission is, I have been trying more and more to think about what we do next. The problem is you build something, everybody sees it and it becomes almost a fixture of the universe for astronomers.

Space missions can never be like that, unlike ground-based telescopes, which generally run for decades and have new instruments put on.

Hubble is unique in that sense. With most space missions, if they live ten years, that's good - Hubble will have done 25 years in 2015. So that is going to come to an end - it could be next year, it could be five years' time... If you don't start thinking now about what's going to come afterwards, then it never will. It will never happen. Even now, we're looking at a decade between when Hubble ends and [when the ATLAST mission] will take place, which is an awfully big gap for access to the ultraviolet and visible part of the spectrum from space. James Webb [Space Telescope] will be there, but that's infrared only.

So I've tried, from a European and UK perspective, to try and push this idea that we need a new mission. I'm not alone - there are other people in the US who are similarly interested, they also see the need and are also trying to push the idea. There's been quite a lot of resistance because everyone has been concentrating on getting James Webb sorted out, because it's been difficult... and the idea of going beyond that has been quite hard to get any focus on...



A concept design for the ATLAST telescope mission

If ATLAST takes on a segmented mirror design, it's likely to be launched using an Evolved Expendable Launch Vehicle (EELV)



Interview New Hubble Telescope

Are there any technologies that we've used on telescopes already that will be utilised for this new ATLAST mission?

We will be taking technologies and testing - in the sense of what we do with ATLAST - the way of deploying mirrors in space, because James Webb will have a mirror that will unfold. We will almost certainly need something similar for ATLAST because we probably won't have a big enough launcher to get a full mirror into space without having it folded up. So that will be something to take from James Webb.

One of the things that we will need if we go to search for extra-solar Earths is a very, very good coronagraph. Currently those are being deployed on telescopes on the ground and so there are a lot of techniques that have been tested by ground-based telescopes [that could be applied] in space. That should get us even better performance because you're in a vacuum, there's less scattered light and the background of space is much darker. So you should be able to take these [technologies] to the ultimate in this particular telescope.

How much will ATLAST cost to build? Will there be any maintenance costs?

The answer is that I have absolutely no idea right now, because we haven't really sat down and tried to cost it out. With a quick and dirty thought about it, it's going to be a few billion dollars or euros or pounds. That's inevitable, because it's such a big telescope. I don't really know how much James Webb is going to cost even though that's nearly built, but conservatively it would be two or three billion dollars [1.2 or 1.8 billion pounds].

Now although ATLAST is bigger, it doesn't need to necessarily cost a vast amount more because we will be able to take some of these ground-based technologies. We'll also, I hope, be able to lean on the fact that the Americans are developing new launches for human space exploration, which will have the capability of taking something like ATLAST into space and put it out at Lagrange 2.

Also it may be that because of that new capability, we will be able to build ATLAST as a serviceable telescope like Hubble was, but obviously much further away from the Earth than astronauts are currently able to go.

Part of the study for ATLAST is to look into more cost-effective materials in the 2020 era. Is that



ATLAST will replace the long-serving Hubble Space Telescope when the mission ends

something that was brought about since the JWST exceeded its budget?

Not really. The thing about the James Webb, and the real reason that it exceeded its budget, is not because of what it's made of - it's because of the complexity of trying to bring all of the systems together and the fact that it just takes time to do that. People hadn't really, I think, completely understood how long it would take to do all of the testing, to get all of the various instruments and to make sure that everything works, because [nothing like this] had ever been done before.

The James Webb experience, I think, is really useful for something like ATLAST. When we design the programme [based] on how it all comes together, because it's not something that you test on the ground, we'll actually have a better idea of how to plan for it, which will hopefully help to keep the cost under control.

The materials aspect is also important because that's about being able to make the big mirror, or the segments of big mirrors. Things need to be lightweight - there was a lot of work going into making lightweight mirror segments that will have the optical quality that we need and James Webb won't have the optical quality that we need, so the mirror technology is a step further forward from [that starting point].

What do you think the ATLAST mission will eventually help us to achieve?

Well, it will be a general-purpose mission, so will study just about anything you want to study in space - from planets all of the way through to distant galaxies. But for me the most exciting thing [is that it will be] big enough to hone in on the habitable zones around nearby stars within say, 10 to 20 parsecs. That's about 30 to 60 light years and it will be able to detect Earth-like planets orbiting those stars directly. If it can do that, it can image them, take a spectrum and [we'll be able to] figure out the biological processes going on.

If you're imagining the Earth 20 parsecs away and if you're observing it, then it will be this tiny, single pixel of blue light. If you actually took a spectrum of it, you would see oxygen, ozone, methane, carbon dioxide in proportions that will tell you that there's biological activity. So it really would be answering the 'Are we alone in the universe?' question.

How much better is it than the JWST?

Well the JWST is smaller in size and mirror area. This will be two to three times the mirror area and what makes it better is the improved precision you

What will it see?



ATLAST will be able to see space objects with unprecedented details



It will be able to directly observe distant Earth-like exoplanets



Professor Barstow thinks it will tell us if there is alien life in the galaxy



The mission aims to answer the big question in science: Are we alone in the universe?

“It really would be answering the ‘Are we alone in the universe?’ question”

get. Better resolution, more collecting area and the full range of wavelengths from ultraviolet all the way through to infrared. The James Webb Space Telescope is just [optimised for] infrared.

When will ATLAST be launched?

I would say that the earliest launch date anyone could conceive is 2030. I think in reality it's not likely to be that soon, because these things always take a bit longer than you hope. [It's] something that's relatively expensive but still tiny compared with what people spend on defence and quite a lot of other things in their budgets. It's still quite hard to get the politics sorted out for something like that, particularly with something that's going to require partners.

How long will it take to build?

The James Webb Space Telescope started maybe five or six years ago, so it's about a ten-year build programme to finally get to the stage of having a working instrument in space.

ATLAST is likely to make a large leap in observing capabilities. Does this mean we won't be able to foresee the diversity and direction of what it will be able to achieve?

There are a lot of things that it can do for every single astronomer that wants to use it. [It will offer] an enormous range of science and things that we don't yet anticipate it can do. Hubble has been studying the atmospheres of extra-solar planets, transiting planets

in particular. How could anybody have imagined that when Hubble was launched? I certainly didn't.

Is not knowing exactly what it's capable of a worry for astronomers?

Oh, it's never a worry! It's a fantastic and exciting thing. Astronomers are very bright people and they are always trying to find new ways of using existing instruments to push further and deeper and, more precisely, in whatever field it is they're working in.

Will ATLAST actually work with the JWST when it's launched?

No chance. The JWST will be long gone, unfortunately - assuming that the James Webb goes in 2018, which is the current plan. It is only about a five- or six-year mission and I don't see it lasting much longer than that. But sometimes things roll on for ten years, so I suppose there is a very small chance that it might overlap, although it's not an overlap I'd expect.

Personally, how successful do you think ATLAST will be?

Well, one of the problems is that I should probably have retired by the time it gets launched, which is one of the difficult things of working on space projects - the timescale. I think, if the only thing that it ever did was to answer that big question, ['Are we alone in the universe?'], it would have been a success. I think it will answer that question. ●

Prof Barstow is president of the RAS

Light echo

RS Puppis has created one of the best examples of a special space phenomenon...

The bright spot at the centre of this image is RS Puppis, a Cepheid variable star 6,500 light years from Earth. It has an unusually long period for a variable star, increasing in brightness almost by a factor of five over 40 days, but that's not the most remarkable thing about it.

RS Puppis can be found right in the middle of a thick cloud of stellar dust that, combined with the variable star's pulsations in luminosity, creates one of the finest examples of the phenomenon known as a light echo. This is like a sound echo but on a much larger scale: light reflecting off the dust clouds has further to travel than the light travelling directly to Earth, so an illusion of a light wave moving through the cloud is created. ■



Cepheid variable star RS Puppis
was captured in visible light by
the Hubble Space Telescope

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Gemma Lavender



Senior staff writer
■ Gemma has been
elected as a fellow of
the Royal Astronomical
Society. She is a keen
stargazer and telescope
enthusiast on **All About
Space** magazine.

A weightless
environment causes
many stresses and
strains on the body, so
simulating gravity is
extremely useful

SPACE EXPLORATION

How can rotating spacecraft mimic gravity?

Andrew Barton

Rotating spacecraft have been seen as
useful because the rotational motion
creates acceleration. This acceleration
can be tuned, with careful design,
to simulate the acceleration we are
subjected to by gravity here on Earth.

Simulating gravity is an extremely
useful ability for space travel, because
the human body reacts quite badly
to this weightless condition. One of
the most noticeable side effects of
prolonged microgravity is the loss of
muscle and bone density. A stint on

the ISS results in a one per cent loss
in bone mass per month on average,
which takes months to recover from. If
we were able to simulate gravity, even
partially, this could drastically reduce
these stresses on the body, enabling
much longer space flights. **JB**

ASTRONOMY

Is it possible to see the Moon and Sun at the same time at latitudes where the Sun doesn't set?

Todd Cooper

As long as they are oriented
appropriately with Earth it's possible
to see the Sun and the Moon
simultaneously from anywhere.

Viewing the Moon at extreme
latitudes does lead to interactions.
At the poles the Moon is only visible
for half the month, because for a full
Moon it has to be opposite the Sun,

which at the poles (during summer)
would be on the opposite side of the
Earth. This means that on the poles,
you only see the Sun and Moon in
early and late crescent phases. **JB**

It's possible to see the Sun and
Moon in the sky at the same
time anywhere on Earth



We're not fully certain of how the Red Square nebula got its unusual shape

 DEEP SPACE

How did the Red Square nebula get its odd shape?

Jack Brown

We still aren't sure why this nebula (MWC 922) has an almost perfectly symmetrical square shape but it's thought that it's thanks to the way in which MWC 922 ejects material and our relative viewing position.

This planetary nebula has a dying star at its core, which ejects gas and dust into its surrounding as it expires. It's thought to be a bipolar nebula that spews out this material in two cones that emit from opposite sides of the star. From Earth we can see these two cones of ejecta from side-on, but they point in opposite directions. As the ejections of dust and gas are expelled in almost a 90-degree cone the nebula seems square. **ZB**

 SOLAR SYSTEM

Is Hyperion made of a spongy material?

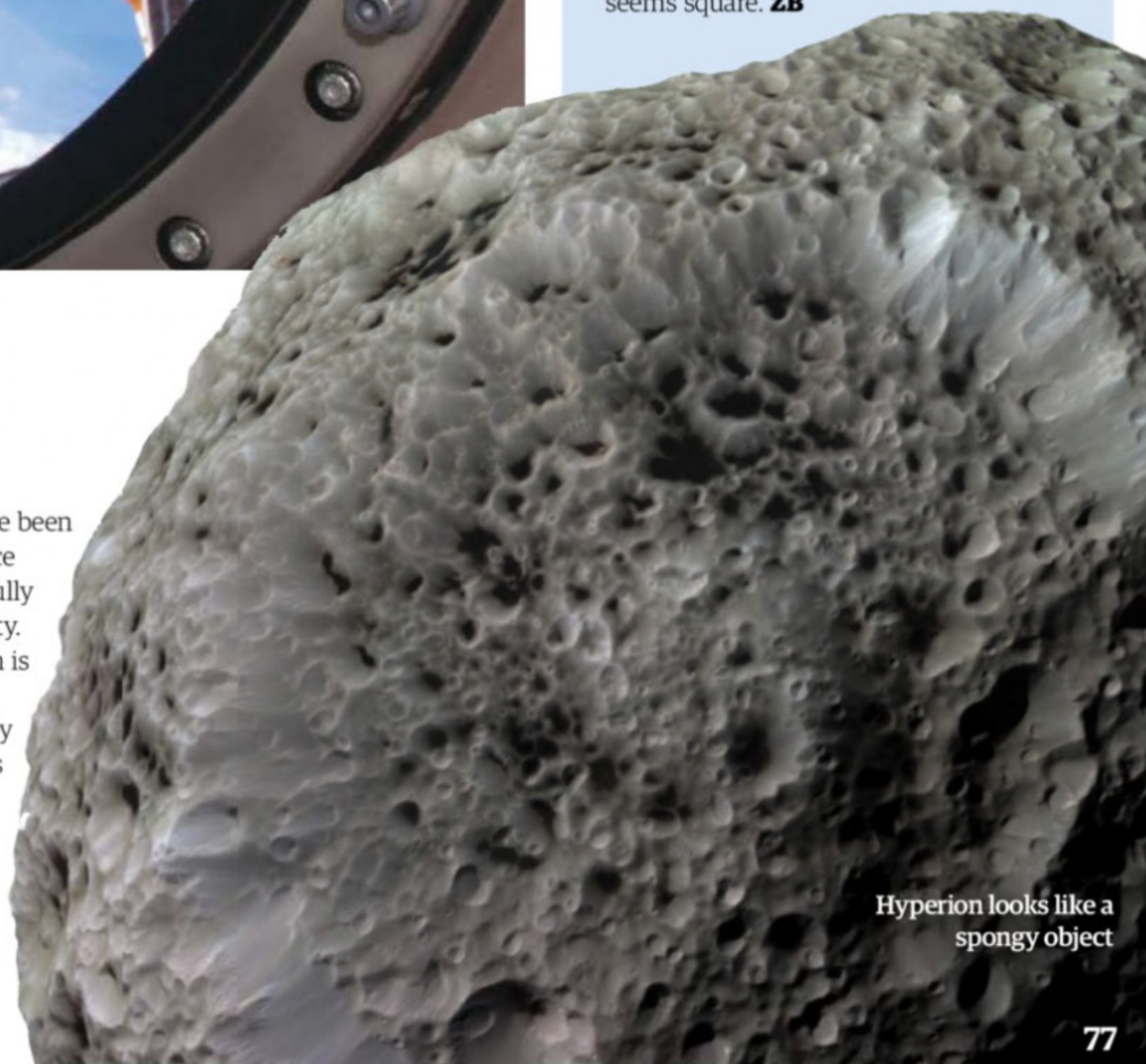
Jessica Wills

The composition of Saturn's moon Hyperion is very different to that of a sponge. We believe the moon is most likely made up primarily of water ice, with only a small amount of rock and other frozen molecules such as carbon dioxide and methane. Sponges are generally made of long, stringy polymer molecules, which aren't commonly found outside Earth.

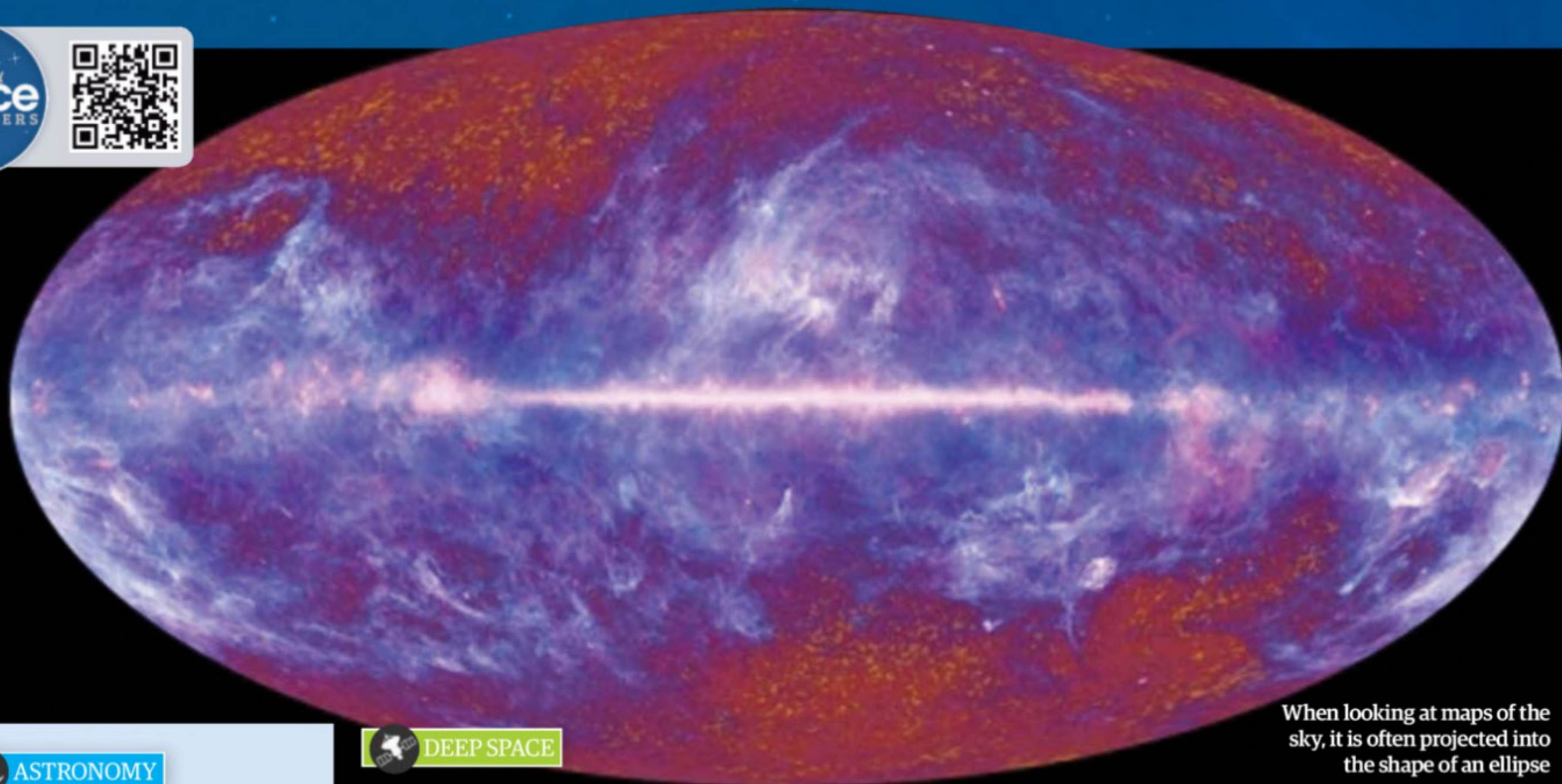
Hyperion does have some similarities with a sponge, as it's

thought the moon could have been formed by small chunks of ice and rock that haven't been fully compacted together by gravity. This might be why the moon is so porous.

The most notable similarity of Hyperion to a sponge is its appearance. Many unusual, sharp-edged craters cover the moon's surface, making it look much like a soft sponge-like world. **SA**



Hyperion looks like a spongy object



When looking at maps of the sky, it is often projected into the shape of an ellipse

ASTRONOMY

Is it dangerous to look at an eclipse during its totality?

Eric Zoot

It is extremely dangerous to look at the Sun, even if the Moon is obscuring its disc during a total eclipse - this is the stage also known as totality.

Unless you have solar filters or a dedicated solar telescope from a reputable dealer, never risk even taking a quick peek at our Sun, whether it's during a solar eclipse or not. The Sun's intense light can cause irreparable damage to your eyes.

As well as the equipment already mentioned, you could use a telescope or one barrel of a pair of binoculars to project an image of the Sun on a white card, or use a reflection of an eclipse in a bowl of water to observe an eclipse safely - without risking your eyesight! **GL**



Ensure that you use substantial protection when observing an eclipse

DEEP SPACE

Why are maps of the universe elliptical?

Felicity Gill

We often see elliptical sky maps because of something called Mollweide projection. This is used to convert our 3D spherical measurement of the sky into a flat, 2D representation. Unfortunately the conversion from 3D

to 2D is not a perfect one and sacrifices in accuracy have to be made.

With a Mollweide projection, angle and shape are sacrificed in order to preserve proportions in area. This is why they're used to create maps of the sky and the globe.

Area is often seen as the more-important property being observed. In a perfect world we wouldn't have to make these compromises but as we currently operate in a 2D display-dominated world, displaying 3D data can prove to be tricky. **SA**

DEEP SPACE

Has the Milky Way collided with other galaxies in its past?

Laurence Carangid

According to a European team of astronomers, it's thought that our Milky Way galaxy collided with our closest spiral, Andromeda, around 10 billion years ago.

It's been speculated that in about 4 billion years' time, the pair are set to collide, but their previous encounter such a long time ago explains their structures and satellites - something that's been difficult to account for.

For this to have happened, astronomers suspect that there are no dark matter particles in either structure. If there were, then the pair would have stuck together. Instead, the team employed dark matter's theoretical rival, MODified Newtonian Dynamics (MOND), which suggests that the two galaxies passed each other, drawing matter from each other into long thin arms. **ZB**



It's thought the Milky Way could have interacted with Andromeda in its history

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SOLAR SYSTEM

Do we come from comets?

Howard Bannister

There are theories that water and vital chemical building blocks of life may have been delivered to early Earth by icy comets.

How life first began on Earth is still one of the great mysteries. Liquid water is assumed to be essential for life, but it's thought that there wasn't any when Earth first formed. Delivery

of this water by comet impacts may be the answer, as comets are mainly composed of ice.

Another vital component for life is amino acids, organic compounds that join together to form complex proteins. For a long time it was thought these molecules could only be created by biological processes, but how did they turn up on Earth?

Research has shown that the impact of comets on Earth may have brought these molecules with them. Alternatively, the impact may have provided the right conditions for these molecules to form some form of life.

We still don't know for sure, but if these theories are true, it could be possible to say that our origins did come from comets! **ZB**

Some scientists believe the beginnings of life originated from comets smashing into Earth

SPACE EXPLORATION

How is plutonium used in space exploration?

Helen Hall

Experts say that plutonium-238 is crucial in providing electricity for a spacecraft that's too far away from the Sun to depend on solar power. This radioactive isotope has a half-life of 87.7 years.

Plutonium can be used as a heat source in radioisotope thermoelectric generators (RTGs). These generators have been used in spacecraft such as Voyager 1 and 2, as well as Cassini-Huygens, New Horizons and the Mars Science Laboratory to great effect.

We can't deny that this element is important for space exploration. However, unluckily for us NASA is running out of the isotope. Until we have a readily available and affordable source, we may have to find an alternative way to power future spacecraft. **GL**



The Mars Science Laboratory uses plutonium-238 for long-term nuclear power-generation

Quick-fire questions

@spaceanswers

Why are some binoculars filled with nitrogen gas?

Nitrogen gas is often included in the manufacture of many binoculars, as it prevents the lenses from fogging or filling with water due to condensation.

Who named Jupiter?

Jupiter has had many names throughout history but it was the Roman Empire that had the greatest influence on the planet's name. It was named after the Roman god of sky and thunder.

How do stars move through our galaxy?

Stars orbit the centre of the galaxy, however, this isn't on a perfectly circular path. They also have random motions where they might suddenly move off at a few tens of kilometres per second.

Do black holes die?

Just like stars, black holes have a finite life. They emit radiation called Hawking radiation (named after its discoverer Stephen Hawking) and the more it radiates, the more it shrinks, until it eventually evaporates.

Does the Moon rotate?

Yes, the Moon does rotate. However, it does it in such a way that we only see one side of it

How much time do astronomers spend actually looking through their telescopes?

Professional astronomers spend the majority of their time working on computers. This is especially the case when studying data obtained by telescopes that operate in wavelengths we can't see. They spend a small proportion of their time at telescopes recording data.

How long does a supernova last?

A supernova explosion lasts for a very short length of time, on average around 100 seconds.

Quick-fire questions

@spaceanswers

Are there stars outside standard galaxies?

Yes, there are stars outside galaxies. Astronomers think that when there are collisions or interactions between galaxies, their stars are ripped out.

Does the Sun have any other name?

Our Sun doesn't have other names, however it is put into a class based on its temperature, size and luminosity. As a result, it is referred to as a G2V star.

Is it possible that Stonehenge was built for astronomical purposes?

Thoughts on this are mixed. On the day of the summer solstice, the Sun rises directly over one of the stones. Some think this isn't a coincidence and that it was built to serve as an astronomical calendar in ancient times.

Why does the SETI project search for radio signals in space?

Radio signals are able to travel for very long distances, as well as through large amounts of dust. The most abundant element in the universe, hydrogen, also radiates at this wavelength.

When will Betelgeuse finally explode?

You might have heard that this red supergiant is likely to go supernova very soon. However, this is astronomically speaking - Betelgeuse will explode within a million years.

What exactly does sidereal time mean?

Sidereal time is measured according to the positions of the stars in the sky. In comparison, a sidereal day lasts 23 hours, 56 minutes and 4.1 seconds, while a mean day (the day we're used to) lasts 24 hours.

SPACE EXPLORATION

Why did the Space Shuttles deploy parachutes when they landed back on Earth?

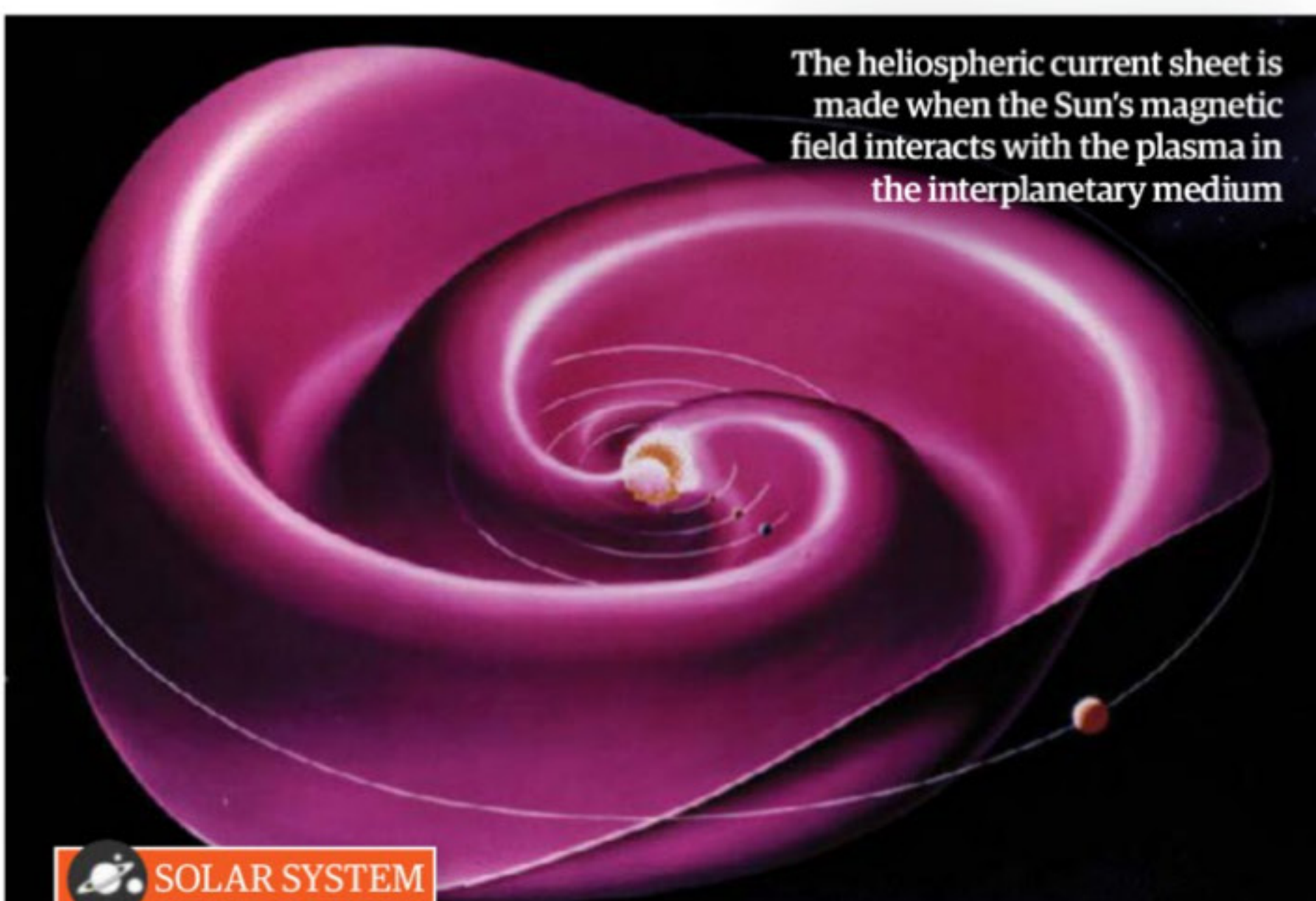
Tim Beckingham

Parachutes were a necessary addition to the Space Shuttle landing procedure to ensure the craft could be slowed quickly.

The Space Shuttle crew had the difficult job of reducing the spacecraft from its orbital velocity of 28,000 kilometres (17,500 miles) per hour, to a complete stop. This was achieved through harnessing atmospheric drag to slow the

initial speed. After the initial slow-down, a slalom-style snaking course was used to further reduce speed.

Despite these efforts, the Space Shuttle landed at a much faster speed than a commercial jet liner, with its final approach velocity around 350 kilometres (220 miles) per hour. To secure the landing, parachutes were used to guarantee a safe stop. **JB**



The heliospheric current sheet is made when the Sun's magnetic field interacts with the plasma in the interplanetary medium

SOLAR SYSTEM

What does 'interplanetary medium' mean?

Lee Naganori

The matter that fills the Solar System, and the region where objects within it move, is the interplanetary medium.

Since it's made of a variety of materials, the interplanetary medium's temperature varies, as does its density, decreasing the further from the Sun it extends. The medium isn't a simple gas, but behaves like a plasma since it

carries the Sun's magnetic field. It also creates double layers when it comes into contact with a planet's magnetic field and conducts charge, which makes the Heliospheric current sheet.

The interplanetary medium extends somewhere roughly between 110 and 160 astronomical units from the Sun and where the solar wind and the interstellar medium meet. **GL**



Space Shuttle pilots had to reduce their craft's speed dramatically to make a safe landing



October 2013 saw observations of main-belt comet P/2013 R3

SOLAR SYSTEM

What is the essential difference between a main-belt comet and a standard comet?

Phil Lambert

Comets spend most of their time in an orbit at a distance comparable to that of Jupiter's distance from the Sun and beyond. However, main-belt comets like to stay a bit closer to the Sun, following nearly circular orbits within the Asteroid Belt. Some of these objects display a cometary dust tail only when closest to the Sun.

There are some who disagree with their naming - notably David Jewitt, who prefers to call them active asteroids because of the dust activity they exhibit. It's thought these nearby comets may have been a source of Earth's water, but some suggest the ratio of certain elements is too low for classical comets to be responsible. **GL**

The radio signal was detected at the Arecibo Observatory

ASTRONOMY

What explains the signal detected by Arecibo?

Benjamin Rosewall

The radio signal bursts, which were recently detected at the Arecibo Observatory in Puerto Rico, have been confirmed but the explanation behind them is not fully clear.

Short and energetic, this isn't the first time we've detected a signal like this. In 2007, the Parkes radio telescope in Australia also detected a rare signal.

While astronomers are unable to pin down exactly where these spontaneous

signals - called Lorimer bursts - come from, what they do know is that they didn't have repeating patterns similar to those thrown out by celestial objects such as stars or pulsars.

Measuring the recent burst, astronomers have been able to get a ballpark figure of how far the signal had travelled. Only lasting three thousandths of a second, it's thought to have travelled from billions and billions of light years away. **GL**

SPACE EXPLORATION

When is the best time to observe zodiacal light?

Gerry Dwight

The best time to observe zodiacal light is around the spring and autumn equinoxes. From the Northern Hemisphere you should look to the western horizon just after sunset during the spring; during the autumn you are best to look towards the eastern sky just before sunrise.

Just like any other astronomical sight you are most likely to spot zodiacal light in a dark environment away from other light pollution. The Moon can also make it difficult to see this phenomenon, so if possible try to view during a new Moon. Zodiacal light is a hazy triangular band of light, which extends from the horizon into the skies. It is created when sunlight shines through small particles of space debris known as cosmic dust. **ZB**

Watch out for zodiacal light around the spring and autumn equinoxes

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Next Issue

EDGE OF THE UNIVERSE

What amazing celestial sights can we see at the edge of space?



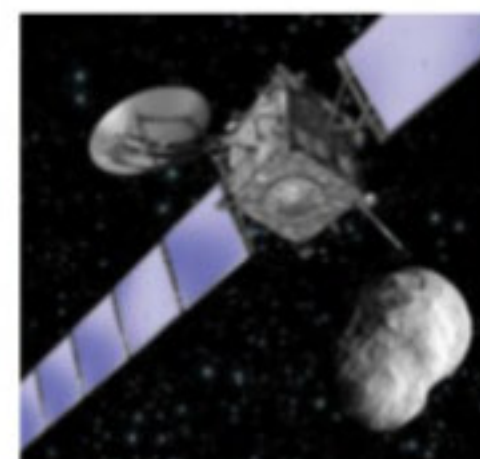
10 INCREDIBLE SPACE ROBOTS

3D space printers, planetary explorers, robotic apes, astronauts and more!



ICE GIANT URANUS

The mission to explore the depths of this freezing gas planet



COMET-CHASING SPACECRAFT

We talk to the team behind the unique comet-chasing spacecraft, Rosetta

SHAPLEY SUPERCLUSTER
REMOTE-CONTROL MISSIONS
TOTAL LUNAR ECLIPSE
GALACTIC GAS STATIONS
STARGAZER: COMET HUNTING
CENTRE OF THE MILKY WAY

In orbit
18 Sept 2014



In this issue...

82 Sizzling summer nebulae

Feast your eyes on the hottest summer sights

88 What's in the sky?

Find the most spectacular nighttime objects

90 Me and my telescope

Readers showcase their best astrophotography images

96 Astronomy kit reviews

The latest essential astronomy gear and telescopes reviewed

Sizzling summer nebulae

Take a tour of some of the treasures held in the warm Northern Hemisphere

Summer: where the days are longer and the nights are shorter. Many look forward to the warmer weather as spring makes way for the extra hours of daylight. But more often than not the astronomer has turned their attention to the most obvious target in the sky - the Sun. Many find that, unless you're willing to stay up late and wait for our star's very last rays to leave the sky and plummet the hemisphere into darkness, night-sky astronomy needs to take a back seat until the cooler and longer nights finally draw in.

It's true that summer is a tricky time of year to get the darkest of skies, but that's not to say that observing its treasures is impossible. Both star-birth nebulae and planetary nebulae - which astronomers like to call faint fuzzies - are well worth pulling out your telescope or scanning the skies with your binoculars for. If you're out of the way of light pollution, and have given your eyes at least 20 minutes to adjust to the darkness, the better the views will be.

As we've already hinted, there are several types of nebulae. Planetary nebulae, dark nebulae and diffuse nebulae are the main ones you'll find in the night sky. However, to figure out

the type you're looking at requires a bit of practise and ample equipment to capture these targets at their very best.

As with any night-sky observing, the larger the aperture of your telescope or binoculars, the more light your instrument will be able to collect. This will make it far easier to see your chosen target in all its glory.

Ensure you familiarise yourself with the night sky before you begin your nighttime observations

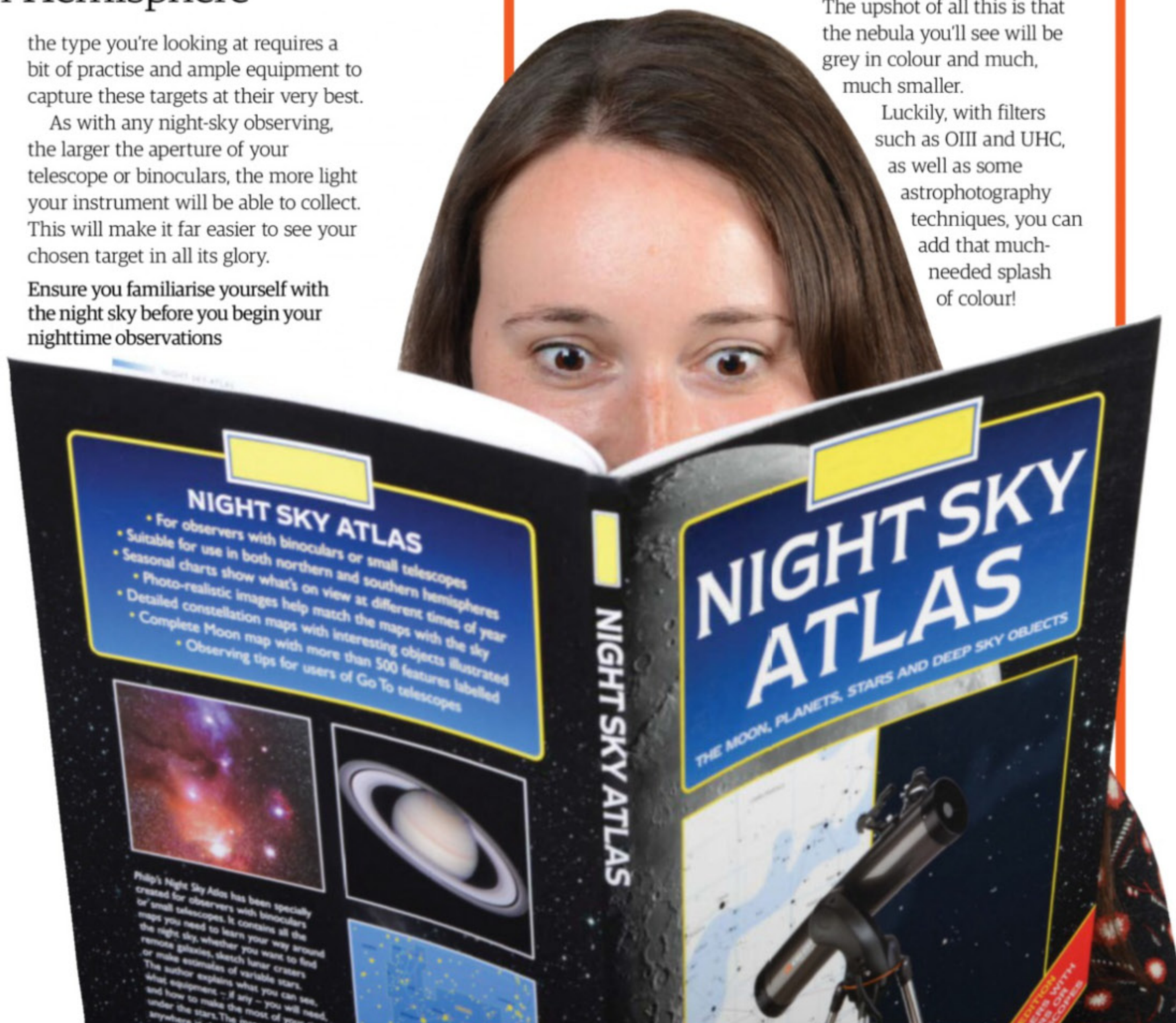


Nebula-hunter's note

In images taken by the likes of the Hubble Space Telescope, nebulae appear large and beautifully

coloured. Remember, the size and the power of professional telescopes does not compare with your back-garden scope. The upshot of all this is that the nebula you'll see will be grey in colour and much, much smaller.

Luckily, with filters such as OIII and UHC, as well as some astrophotography techniques, you can add that much-needed splash of colour!



Meet the nebulae family

From the messy to the beautifully defined, there are many different nebulae to feast your eyes on

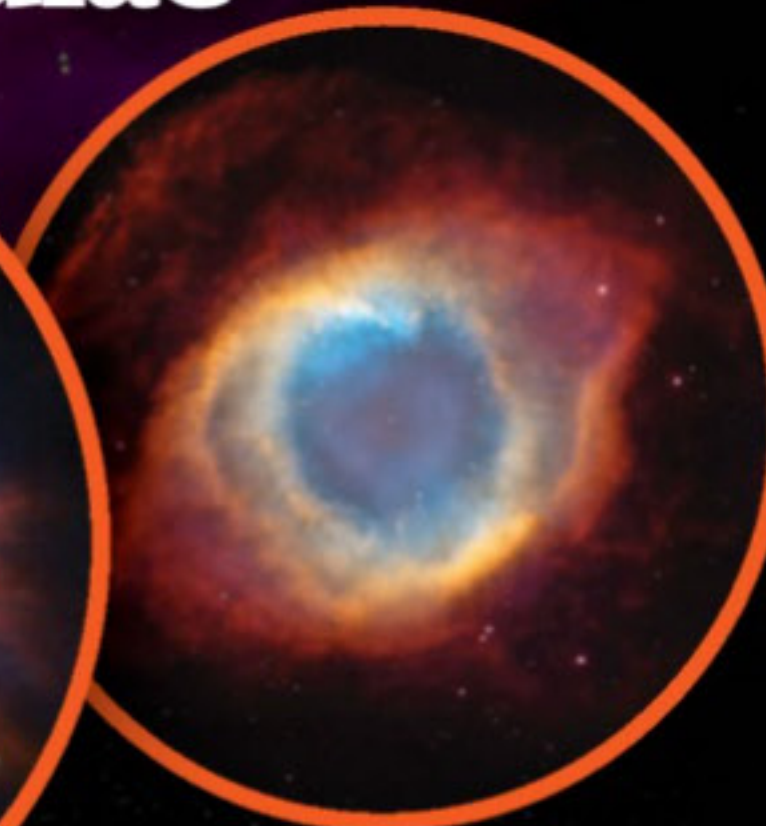
Planetary nebulae



The Eskimo nebula
(NGC 2392)



NGC 6326



The Helix nebula
(NGC 7293)

Diffuse nebulae



The Carina nebula
(NGC 3372)



NGC 6357



The Bubble nebula
(NGC 7635)

Emission nebulae



The Flame nebula
(NGC 2024)



IC 2944



The Monkey Head
nebula (NGC 2174)

Reflection nebulae



The Witch Head
nebula (NGC 1909)



M78



The Ghost nebula
(vdB 141)

Dark nebulae



The Snake
nebula
(Barnard 72)



The Horsehead
nebula
(Barnard 33)



Pipe nebula
(Barnard 59)



Nebulae with your binoculars

Sweep the summer skies for the best nebulae using nothing more than a pair of binoculars



Eagle nebula (M16)

Constellation: Serpens (The Serpent)

Right ascension: 18h 18m 48s

Declination: -13° 49'

Magnitude: +6.0

The Eagle is a bit tricky during the summer nights, but with a careful eye you can spot it. It's home to a cluster of stars that are easier to see than the nebula itself. It's also famous for being the home of the Pillars of Creation, but you'll need a 12-inch telescope or an astrophotography camera to see them.

Trifid nebula (M20)

Constellation: Sagittarius (The Archer)

Right ascension: 18h 02m 23s

Declination: -23° 01' 48"

Magnitude: +6.3

Near to the Lagoon is the Trifid nebula, about two degrees (four full Moon diameters) to the north of M8. Your binoculars will show a bright but hazy nebulous object, but to see the Trifid's four petals, which are parts of this nebula separated by dust lanes, you'll need an eight-inch telescope. A small telescope, of about four inches, will show some of the blue reflection nebulosity in the Trifid.



Lagoon nebula (M8)

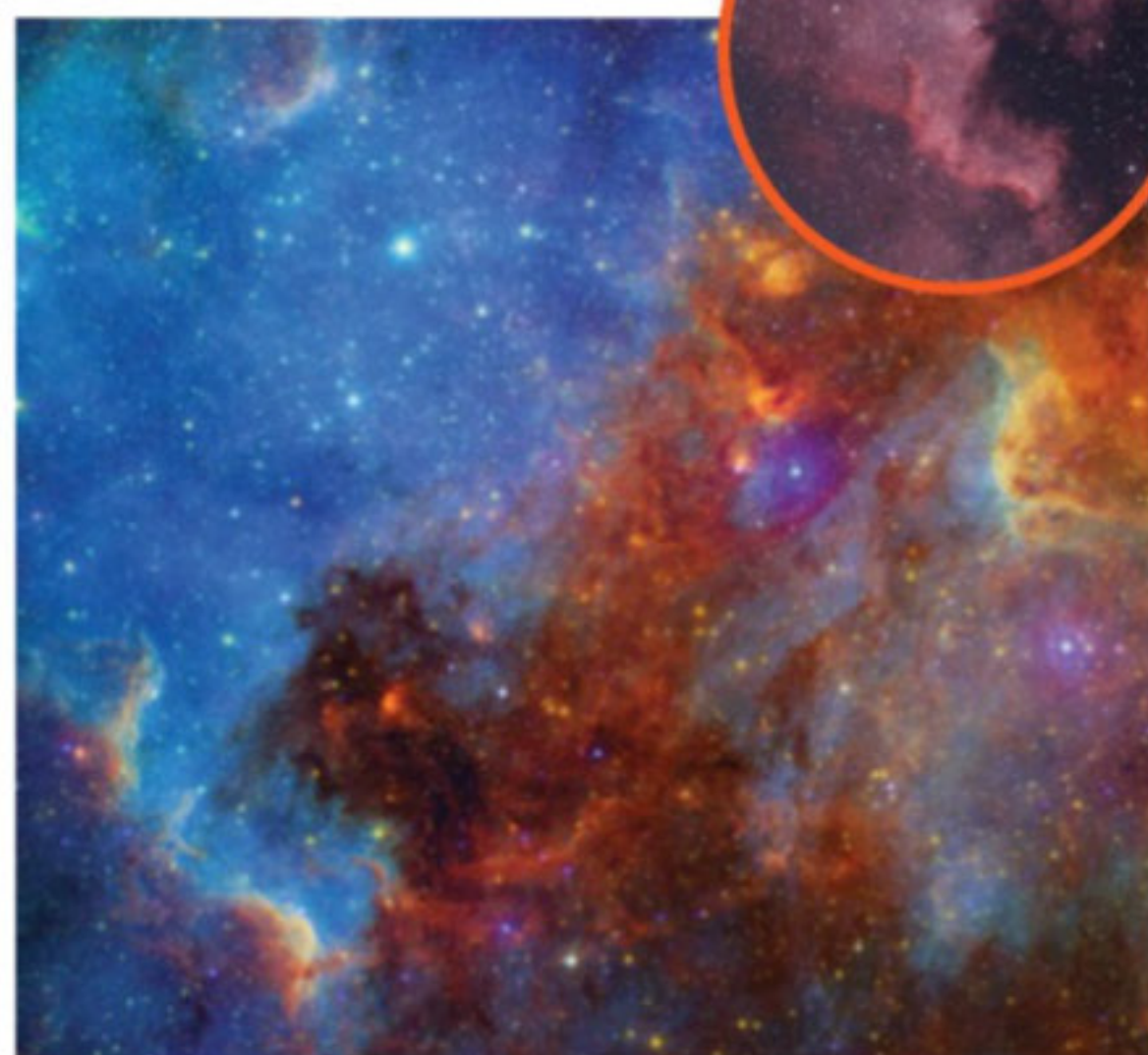
Constellation: Sagittarius (The Archer)

Right ascension: 18h 03m 37s

Declination: -24° 23' 12"

Magnitude: +6.0

Although it appears low in the sky from northern Europe, the Lagoon is a brilliant target for observers with binoculars. You'll see a large fuzzy blob 1.5 degrees across from east to west, which is three times the size of the full Moon. A small telescope shows even more detail, including its characteristic dark dust lane running through the middle.



North America nebula (NGC 7000)

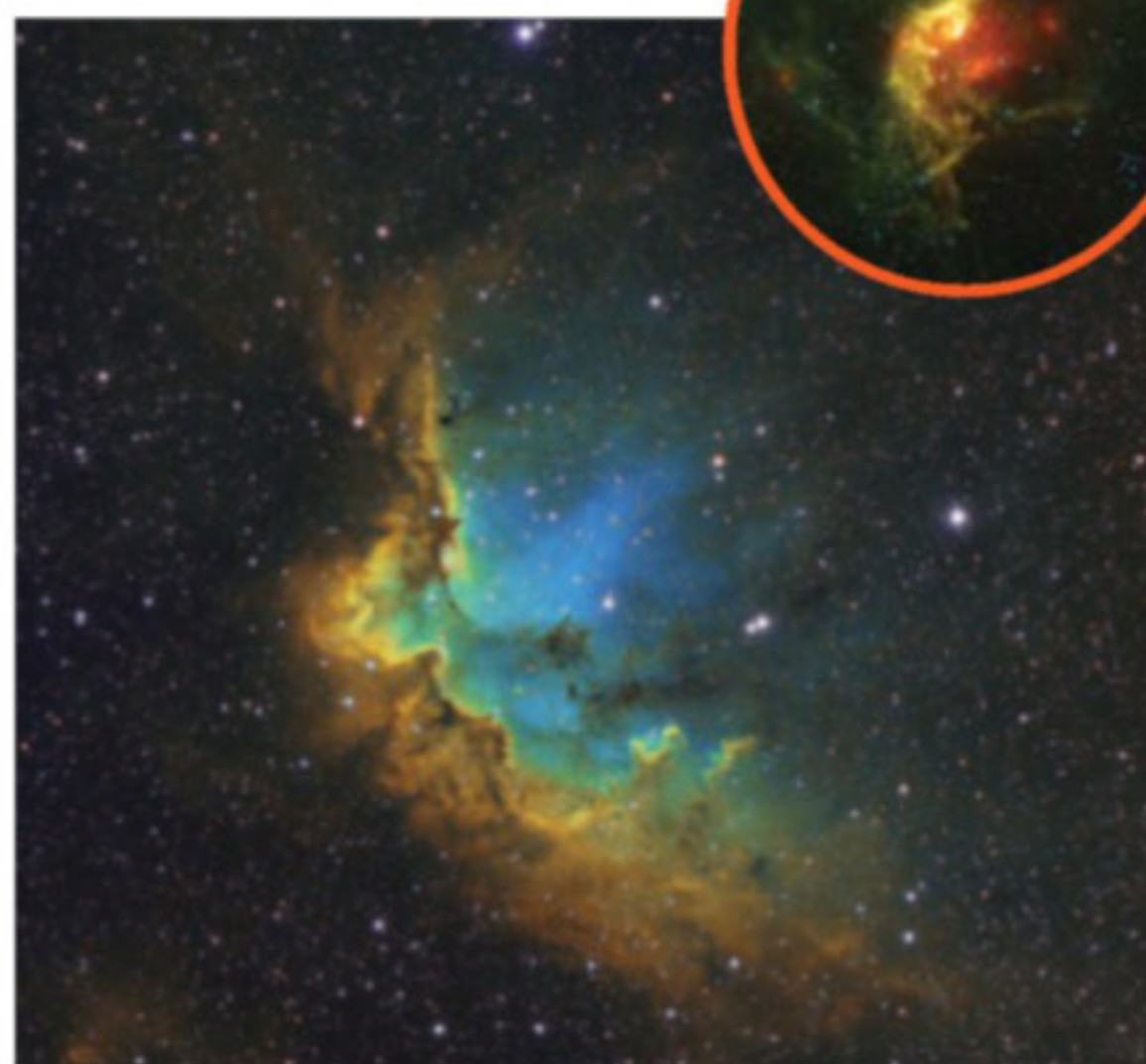
Constellation: Cygnus (The Swan)

Right ascension: 20h 59m 17s

Declination: +44° 31' 44"

Magnitude: +4.0

While its brighter area is visible to the naked eye under excellent conditions, NGC 7000 is best observed with optical aid. At least a pair of 7x50 binoculars will enable you to identify it with ease provided you know where to look.



Wizard nebula (Sh2-142)

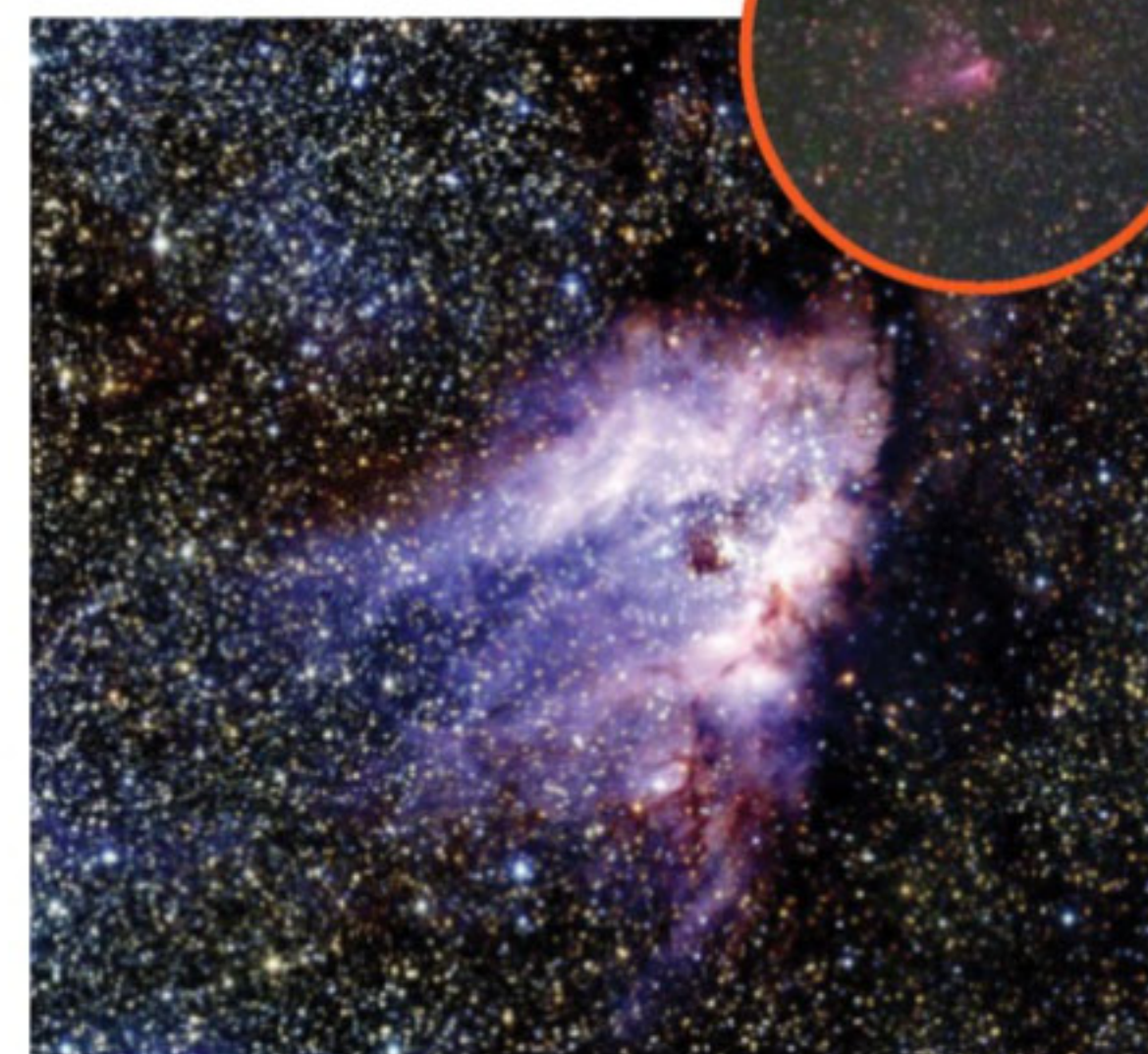
Constellation: Cepheus (The King)

Right ascension: 22h 47m

Declination: +58° 06'

Magnitude: +7.2

This nebula is really tough to spot. Try with binoculars (which are preferred for viewing the cluster of stars) but if not then look through a small telescope using an OIII filter, with averted vision, and you should see a curved shape.



Omega nebula (M17)

Constellation: Sagittarius (The Archer)

Right ascension: 18h 20m 26s

Declination: -16° 10' 36"

Magnitude: +6.0

One of the best emission nebulae in the sky, in binoculars or a small telescope it takes on the shape of the Greek letter omega. If looking through a telescope, then use a UHC filter to bring out the contrast of the nebulosity.



Iris nebula (NGC 7023)

Constellation: Cepheus (The King)

Right ascension: 21h 01m 35.6s

Declination: 68° 10' 10"

Magnitude: +6.8

This is a reflection nebula being lit up by one star. At magnitude seven this doesn't seem too bright to us 1,400 light years away, but in reality is 180 times more luminous than the Sun. You'll see a faint nebula with the star appearing most notable. Though the nebula is slightly brighter than the star, its light is spread over a larger area, so it's harder to see.





Target nebulae with your telescope

Peer deeper into the universe using greater optical aids



Cat's Eye nebula (NGC 6543)

Constellation: Draco (The Dragon)

Right ascension: 17h 58m 33s

Declination: 66° 37' 59.5"

Magnitude: +8.1

The Cat's Eye is one of the best planetary nebulae in the sky, quite bright but small. Unlike most nebulae, you can see colour in the Cat's Eye, with it looking green-blue. Use medium-powered magnification with an eight-inch telescope and you might start to pick out two lobes or rings of material ejected by the dying star in its centre.



Ring nebula (M57)

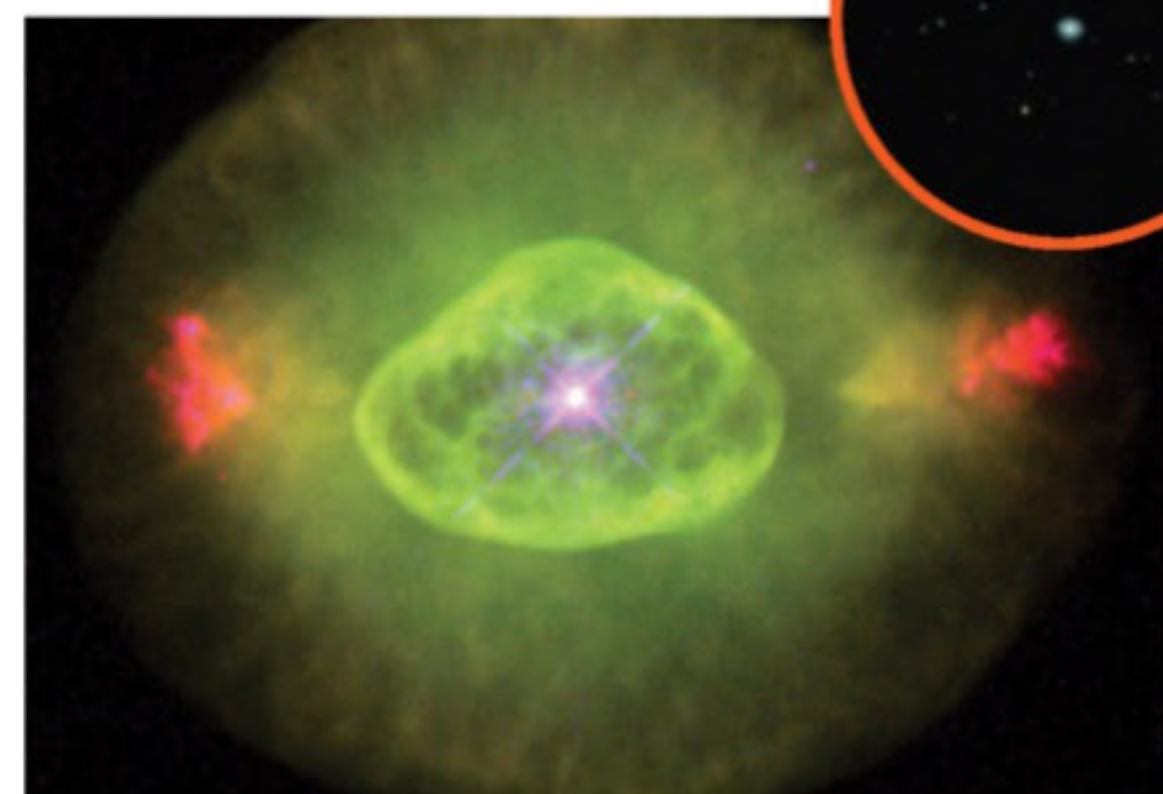
Constellation: Lyra (The Harp)

Right ascension: 18h 53m 35s

Declination: 33° 01' 45"

Magnitude: +8.8

Easy to find in the constellation Lyra, a six-inch scope will pick out its famous hazy structure with a slight greenish tint. For eight-inch scopes at 100x magnification, the greenish hue becomes more prominent and a reddish outer edge appears.



NGC 6826 (Caldwell 15)

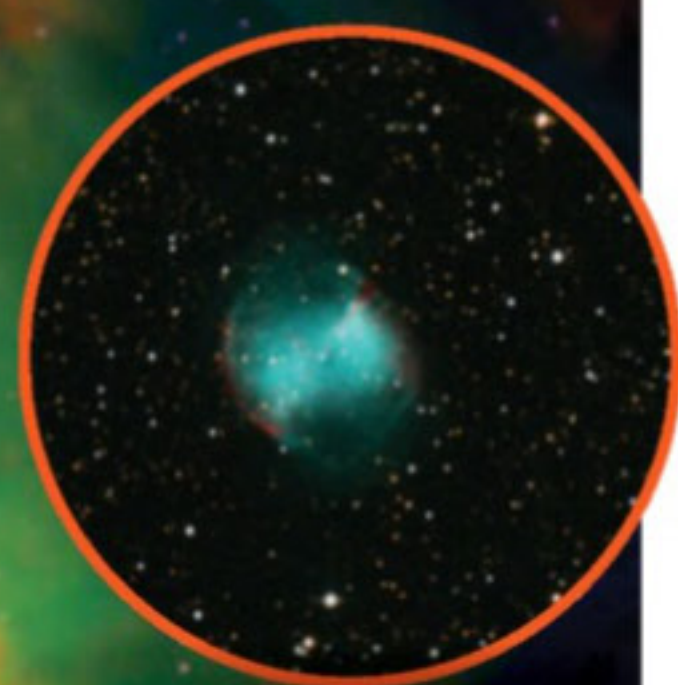
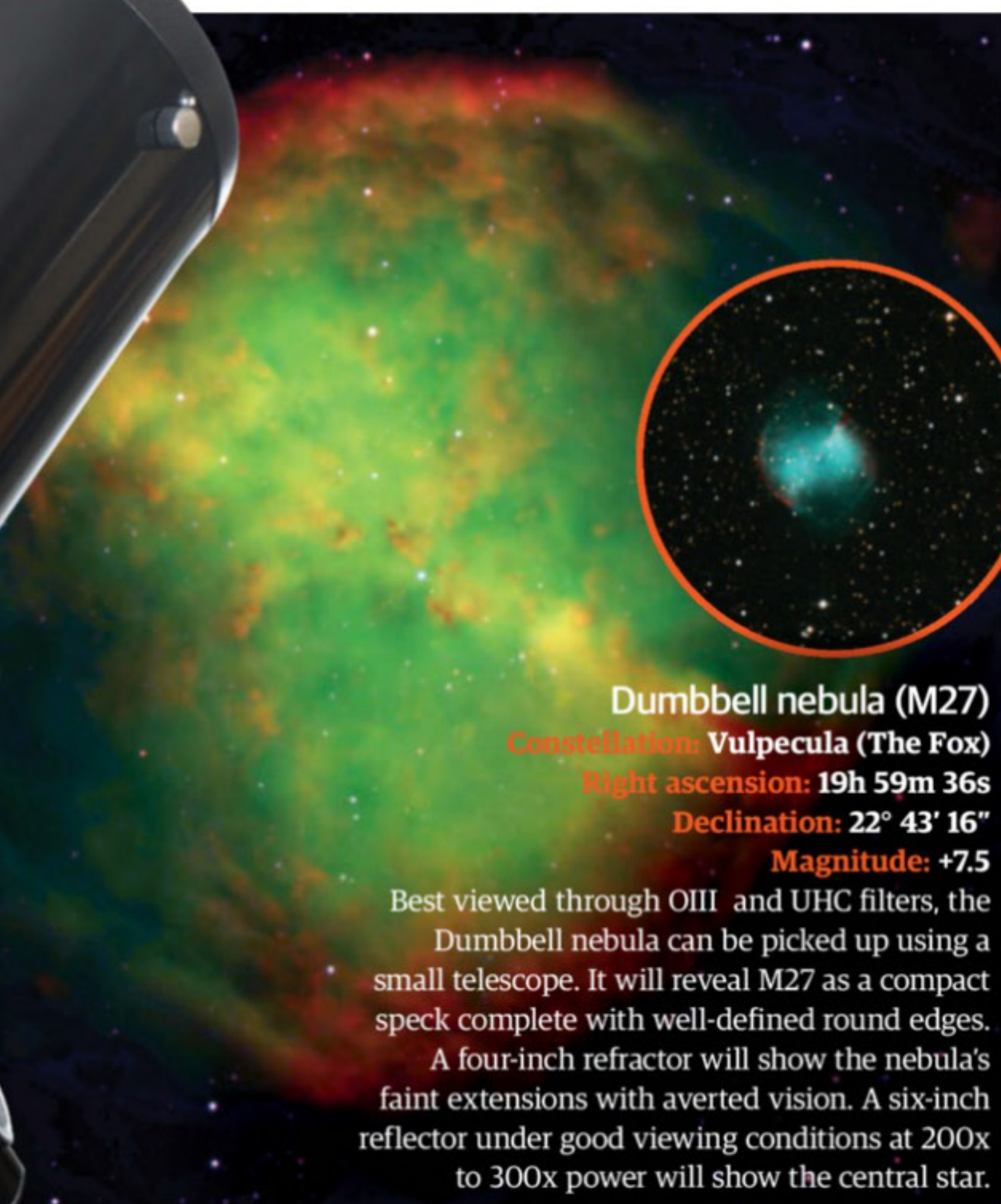
Constellation: Cygnus (The Swan)

Right ascension: 19h 44m 48.2s

Declination: 50° 31' 30.3"

Magnitude: +8.8

This is known as the Blinking Planetary, because when observing it you need to use something called averted vision. When you look just to one side of the nebula, your eye is able to see more light and you'll see it clearer. Look back straight at it and it disappears or fades, so you see it blinking on and off.



Dumbbell nebula (M27)

Constellation: Vulpecula (The Fox)

Right ascension: 19h 59m 36s

Declination: 22° 43' 16"

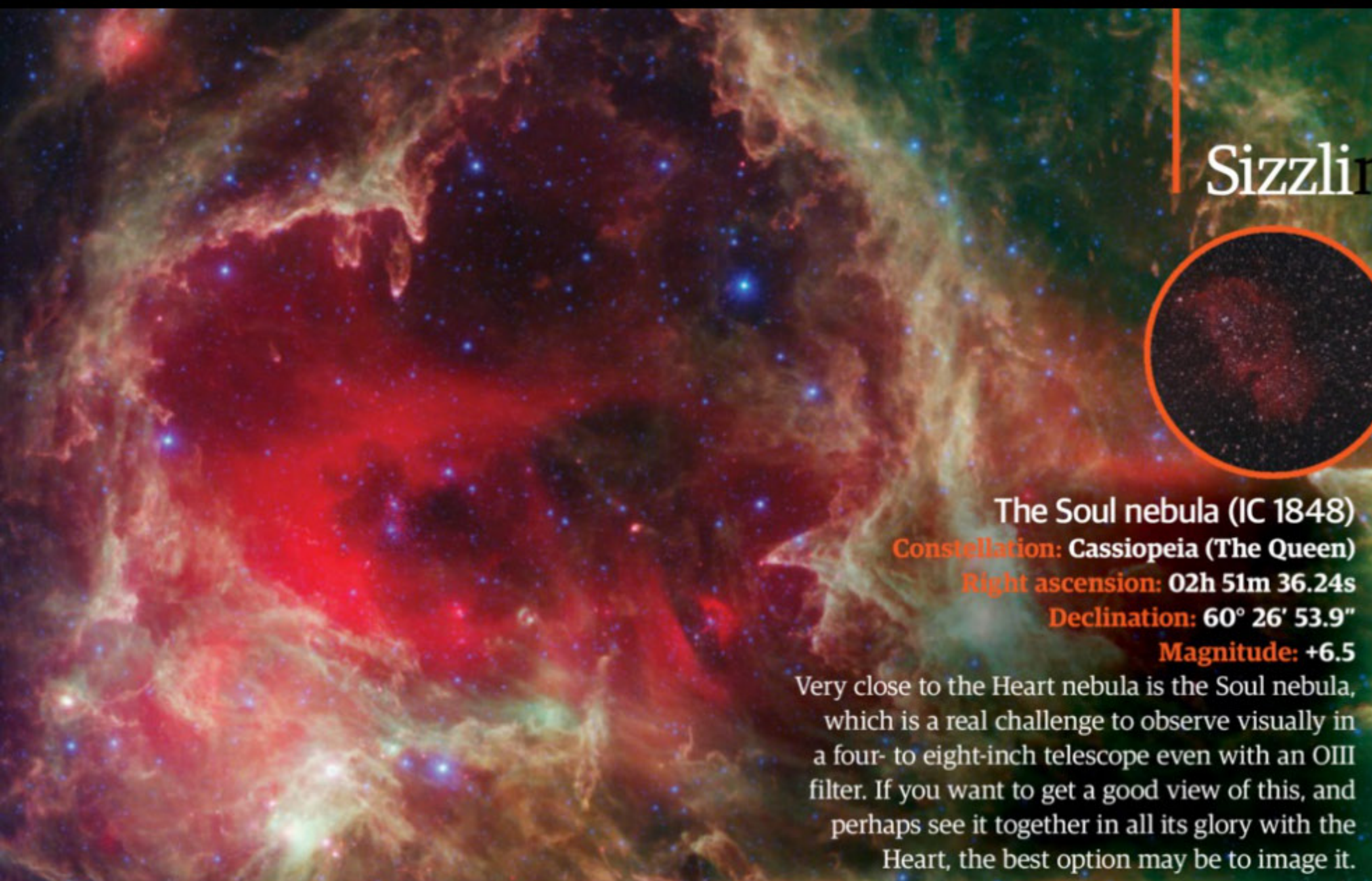
Magnitude: +7.5

Best viewed through OIII and UHC filters, the Dumbbell nebula can be picked up using a small telescope. It will reveal M27 as a compact speck complete with well-defined round edges.

A four-inch refractor will show the nebula's faint extensions with averted vision. A six-inch reflector under good viewing conditions at 200x to 300x power will show the central star.



Sizzling summer nebulae



The Soul nebula (IC 1848)

Constellation: Cassiopeia (The Queen)

Right ascension: 02h 51m 36.24s

Declination: 60° 26' 53.9"

Magnitude: +6.5

Very close to the Heart nebula is the Soul nebula, which is a real challenge to observe visually in a four- to eight-inch telescope even with an OIII filter. If you want to get a good view of this, and perhaps see it together in all its glory with the Heart, the best option may be to image it.



Cocoon nebula (IC 5146)

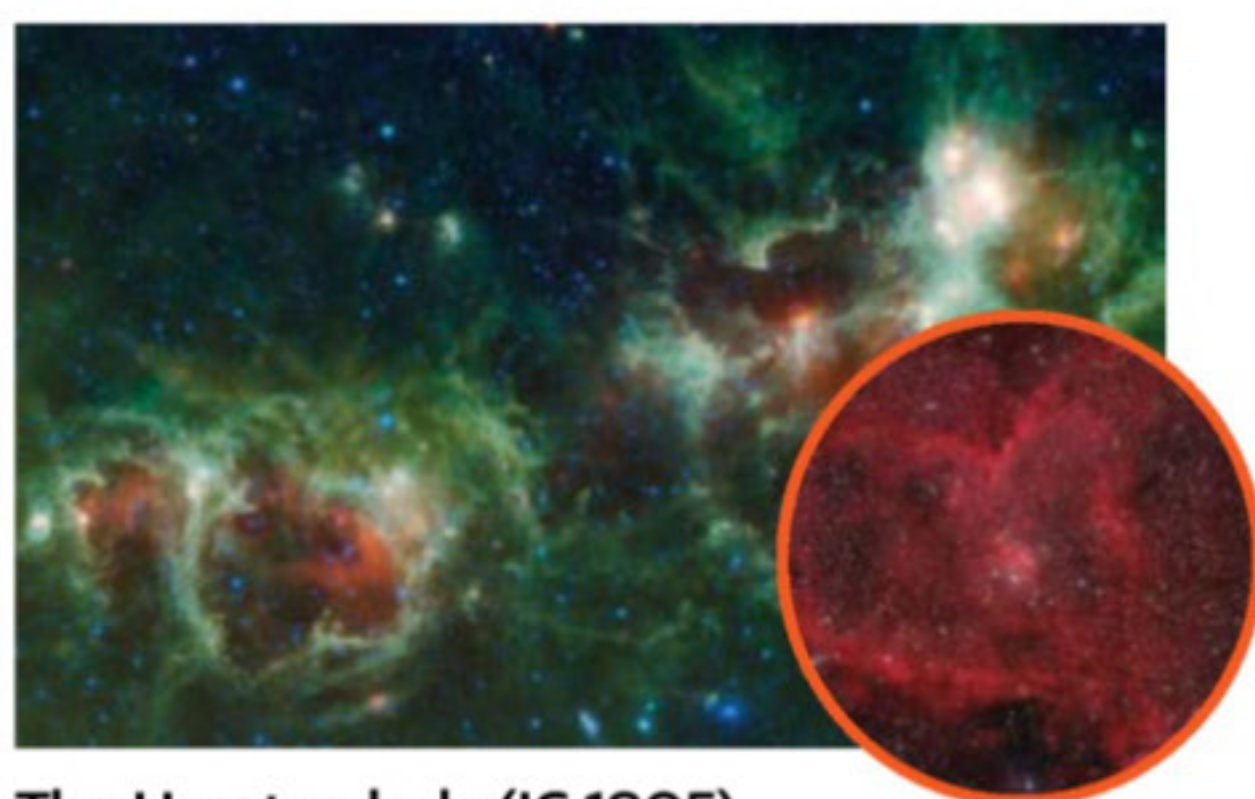
Constellation: Cygnus (The Swan)

Right ascension: 21h 53m 28.7s

Declination: 47° 16' 01"

Magnitude: +7.2

If you're under decent dark skies all you'll need is a four-inch telescope and averted vision to find this dim nebula. It's usually best viewed through larger telescopes and an H-beta filter.



The Heart nebula (IC 1805)

Constellation: Cassiopeia (The Queen)

Right ascension: 02h 32m 35.6s

Declination: 61° 29' 2.3"

Magnitude: +6.5

This area of star-birth can be tricky to find at first, but it has an associated star cluster called Melotte 15 that's a good signpost. By using a low magnification in a small four- to eight-inch telescope, armed with an OIII or UHC filter, you can tease out this heart-shaped nebula from the darkness of space.



Saturn nebula (NGC 7009)

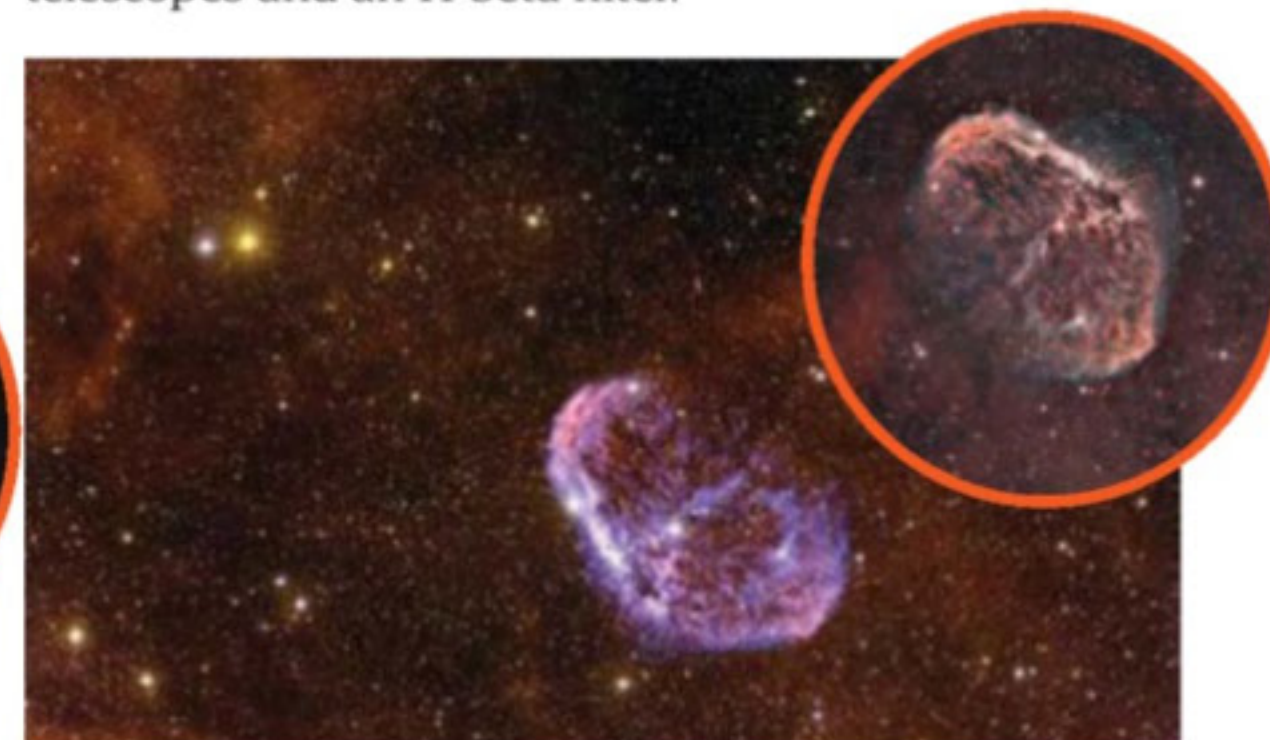
Constellation: Aquarius (The Water-Carrier)

Right ascension: 21h 04m 10.88s

Declination: -11° 21' 48.25"

Magnitude: +8.0

An OIII filter, along with at least an eight-inch scope at 250x magnification, will reveal the bright, blue-green form of NGC 7009. As one of the rare nebulae that shows colour when seen through a telescope, the nebula gets its name because of its shape, which has two protrusions that look like the planet's rings.



Crescent nebula (NGC 6888)

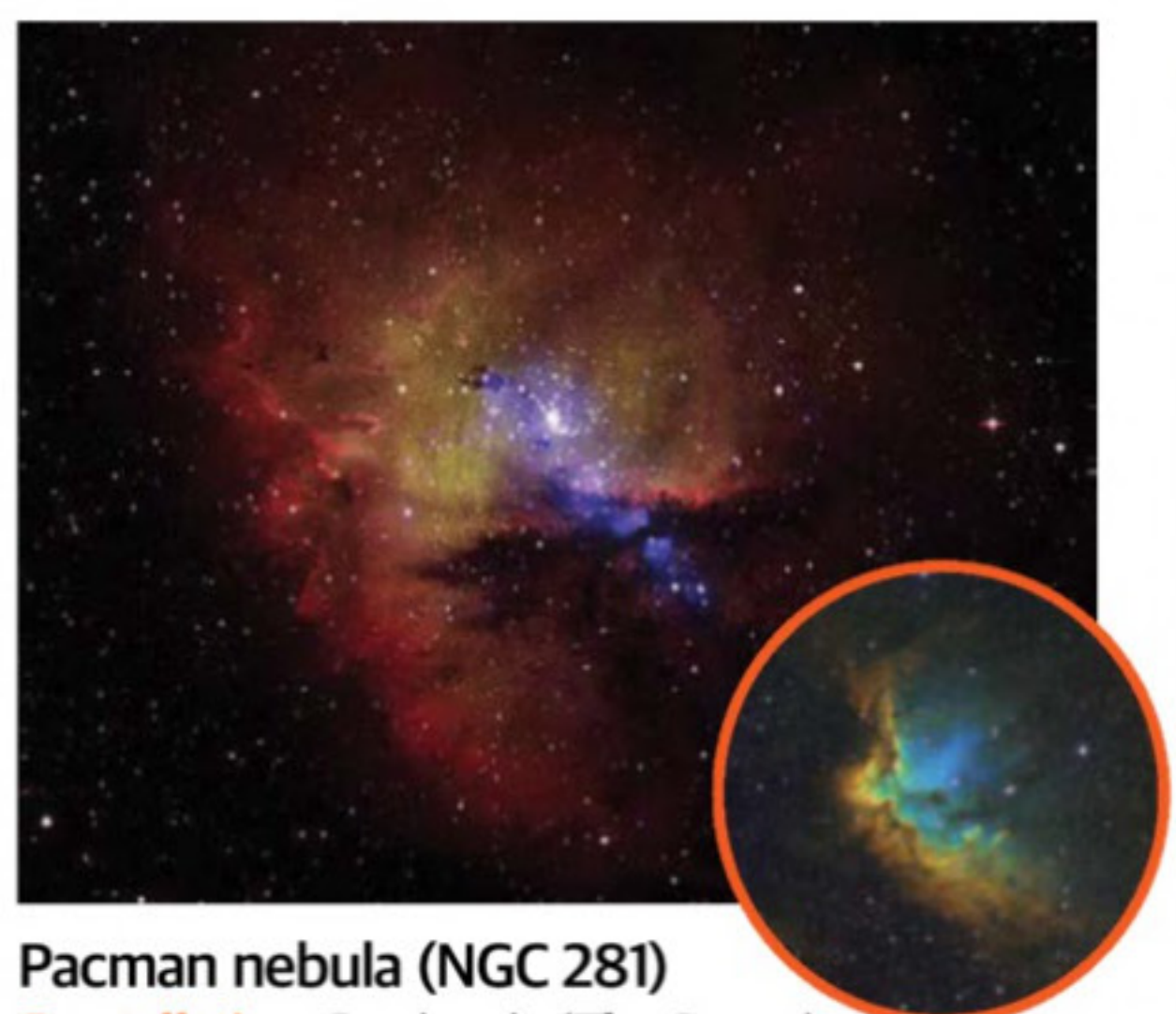
Constellation: Cygnus (The Swan)

Right ascension: 20h 12m 7s

Declination: 38° 21.3'

Magnitude: +7.4

Made of material being ejected by a hot, massive star, the Crescent's light is spread out across its large form. Observers will need a ten-inch telescope with the usual OIII and UHC nebula filters to see it.



Pacman nebula (NGC 281)

Constellation: Cassiopeia (The Queen)

Right ascension: 00h 52m 59.3s

Declination: 56° 37' 19"

Magnitude: +7.4

So-called because it looks a bit like the videogame character when viewed at an angle, the Pacman nebula is a star cluster and nebula combined. The stars are stimulating the gas in the nebula, causing it to emit in hydrogen-alpha light, so a hydrogen-alpha filter will come in useful here!

Win!

Observing and imaging kit

Bundle includes:

Visionary HD 10x50 binoculars

From: www.opticalhardware.co.uk Cost: £110

Ostara Plössl eyepiece kit (comprising 4mm, 5mm, 6.5mm, 10mm, 15mm, 20mm, 25mm, 30mm, 40mm) and case

From: www.opticalhardware.co.uk Cost: £210

Ostara filters (comprising yellow, orange, green, blue, red, crystal moon and polarising) and case

From: www.opticalhardware.co.uk Cost: £60

ZWO ASI130MM Monochrome Imager

From: www.365astronomy.com Cost: £224

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£600

Turn to page 95 for more details on how to enter!



What's in the sky?

Darkness is fleeting in the Northern Hemisphere's summer, but there's still plenty to see if you're prepared to stay up late

Andromeda galaxy

Viewable time: Throughout the hours of darkness

The nearest major galaxy to our own Milky Way returns for prime viewing after clinging too close to the ground during July and August. Visible to the naked eye, the light arriving from this spiral galaxy has been trekking across space for 2.5 million years to get here. It's likely to be the oldest light you'll ever see without binoculars or a telescope.



Brocchi's cluster

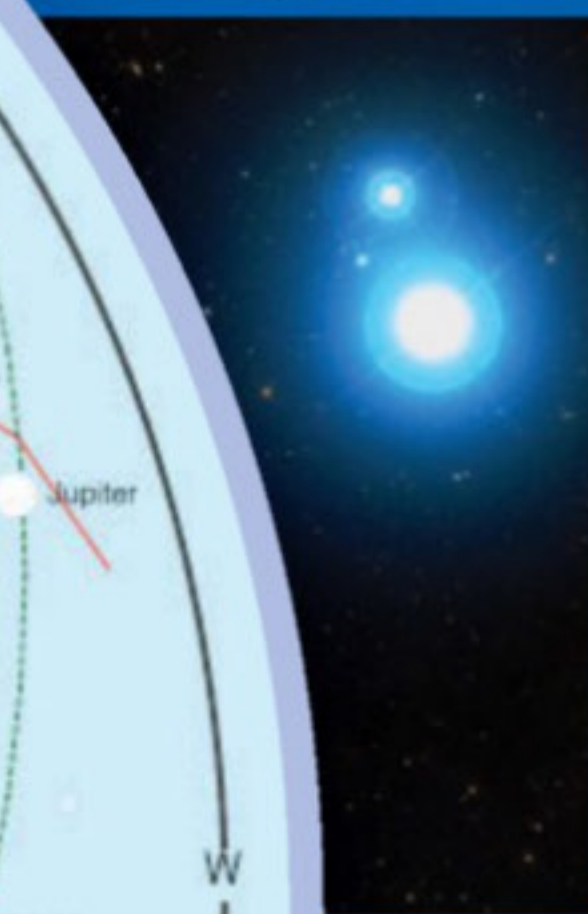
Viewable time: Throughout the hours of darkness

This group of stars - the brightest ten of which resemble a coat hanger - was first recorded by astronomers in the Middle East as far back as 964CE. There has been some debate about whether this really is a cluster or just a chance alignment of stars. Either way, it's one of the best summer objects to track down with binoculars.

Mizar and Alcor

Viewable time: Throughout the hours of darkness

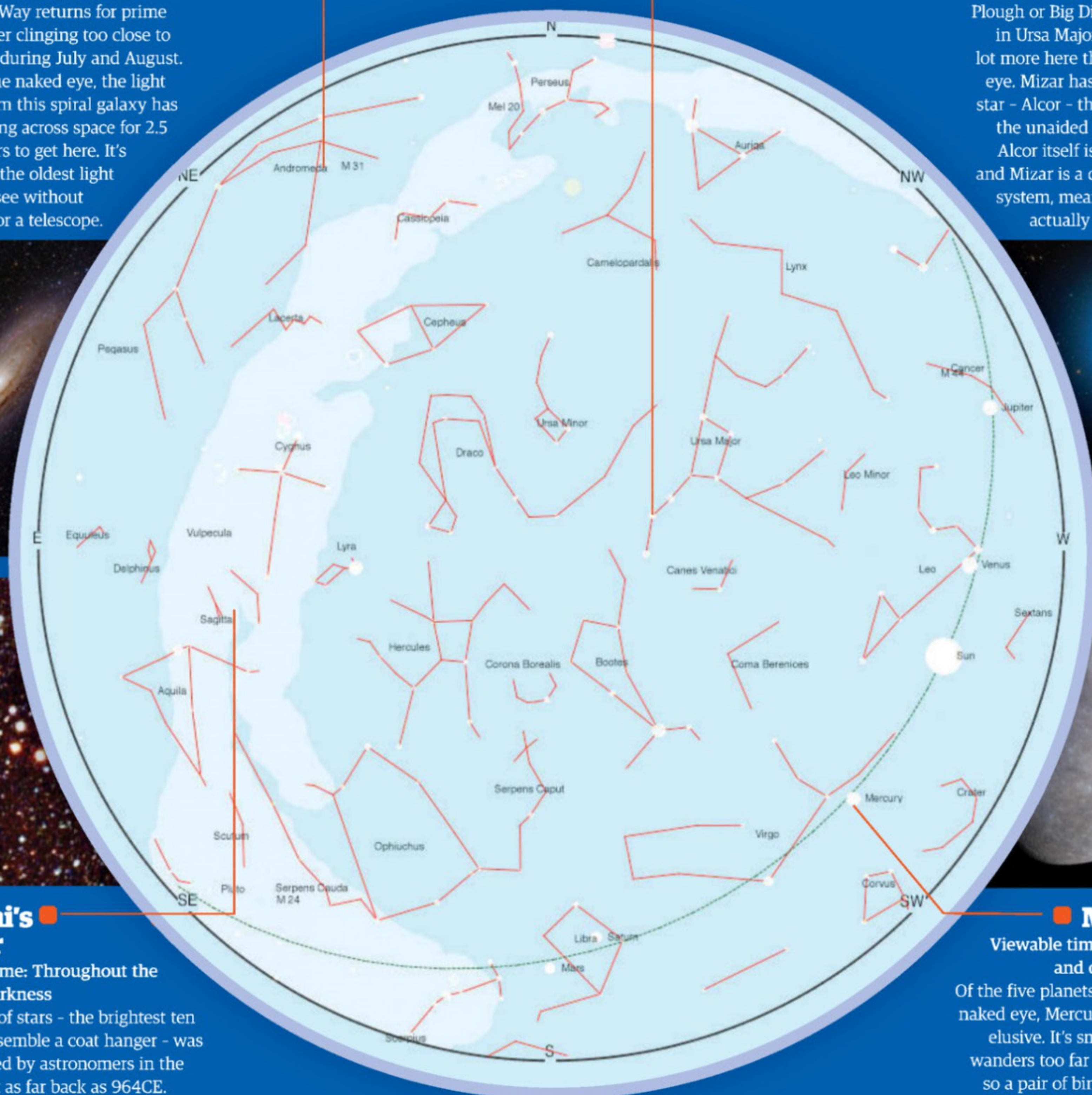
Part of the handle of The Plough or Big Dipper asterism in Ursa Major, but there's a lot more here than meets the eye. Mizar has a companion star - Alcor - that is visible to the unaided eye. However, Alcor itself is a double star and Mizar is a quadruple star system, meaning there are actually six stars here.



Mercury

Viewable time: Just before and during sunset

Of the five planets visible to the naked eye, Mercury is the most elusive. It's small and never wanders too far from the Sun, so a pair of binoculars really helps. You will need a fairly low western horizon free of trees and buildings, but September is the best month of 2014 to track down the closest planet to the Sun.



Northern Hemisphere



Albireo

Viewable time: Before midnight

Sometimes called the Jewel of the Summer Sky, this double star sits at the beak of Cygnus the Swan. The duo has one of the widest separations of any double star, meaning it can easily be resolved in binoculars or a small telescope. The beautifully contrasting colours are the result of different surface temperatures.

Mars and Saturn

Viewable time: Before midnight

Two of the more-popular planets in our system can be seen sidling up to each other in the night sky during August. They will start off close together later in the month, before gradually separating over the following weeks. Though it's hard to make out much detail on Mars right now, Saturn's glorious rings are angled perfectly for a good view through a decent telescope.

Grus Quartet

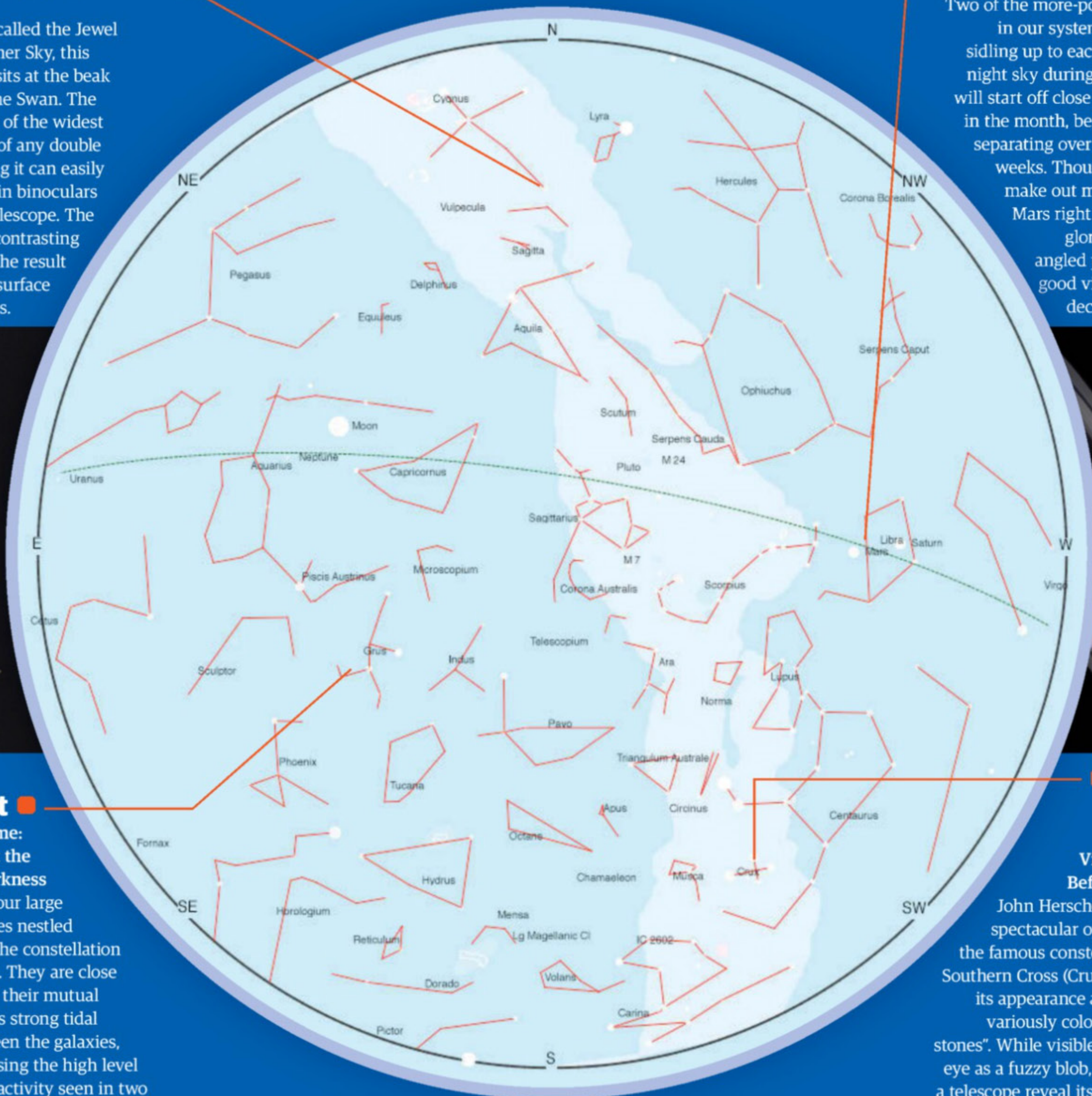
Viewable time: Throughout the hours of darkness

A group of four large spiral galaxies nestled together in the constellation of the Crane. They are close enough that their mutual gravity raises strong tidal forces between the galaxies, perhaps causing the high level of starburst activity seen in two of the quartet. It's thought the four galaxies will eventually collide to form a single entity.

Jewel Box cluster

Viewable time: Before midnight

John Herschel named this spectacular open cluster in the famous constellation of the Southern Cross (Crux), describing its appearance as "a casket of variously coloured precious stones". While visible to the naked eye as a fuzzy blob, binoculars or a telescope reveal its true majesty. Its stars are some of the youngest known to astronomers, at just 14 million years old.



Southern Hemisphere





STARGAZER

Me & my telescope

Send your astronomy photos and pictures of you with your telescope to **photos@spaceanswers.com** and we'll showcase them every issue.

Bill Schlosser

Adrian, Michigan
Telescope: Meade 14" SCT
& Astro-Tech AT65EDQ
quaduplet astrograph



"I shot the Dumbbell nebula and Whirlpool galaxy using the new Meade 14" f/8 SCT sitting on the Celestron CGE Pro mount..."

"I used a QSI 683 WSG-8 camera loaded with Astrodon LRGB and H-alpha, OIII and SII filters.

I achieved six- to five-minute exposures with Nebulosity and guided with a Loadstar camera using PHD through each of the LRGB filters at 2x2 binning and processed with Nebulosity and GIMP. I imaged the Andromeda galaxy using my AT65EDQ scope and QSI 683 camera."

Andromeda galaxy (M31)



Dumbbell nebula (M27)



Whirlpool galaxy (M51)





Steve Coates



Ocala, Florida

Telescope: Astro-Tech 8" Ritchey- Chrétien & Orion EON 3" ED Refractor

"I imaged the Rosette nebula in the constellation of Monoceros using my Orion EON 3" Refractor telescope combined with a QSI 683wsg cooled CCD camera. I used H-alpha, OIII and SII filters and processed using Hubble palette, assigning SII to red, OIII to blue and H-alpha to green..."

"In Canton, Maine, I took a nightscape of the Milky Way over Lake Anasagunticook using a Canon 550D DSLR camera, a Pro-Optic 8mm fisheye lens and 30sec exposure."

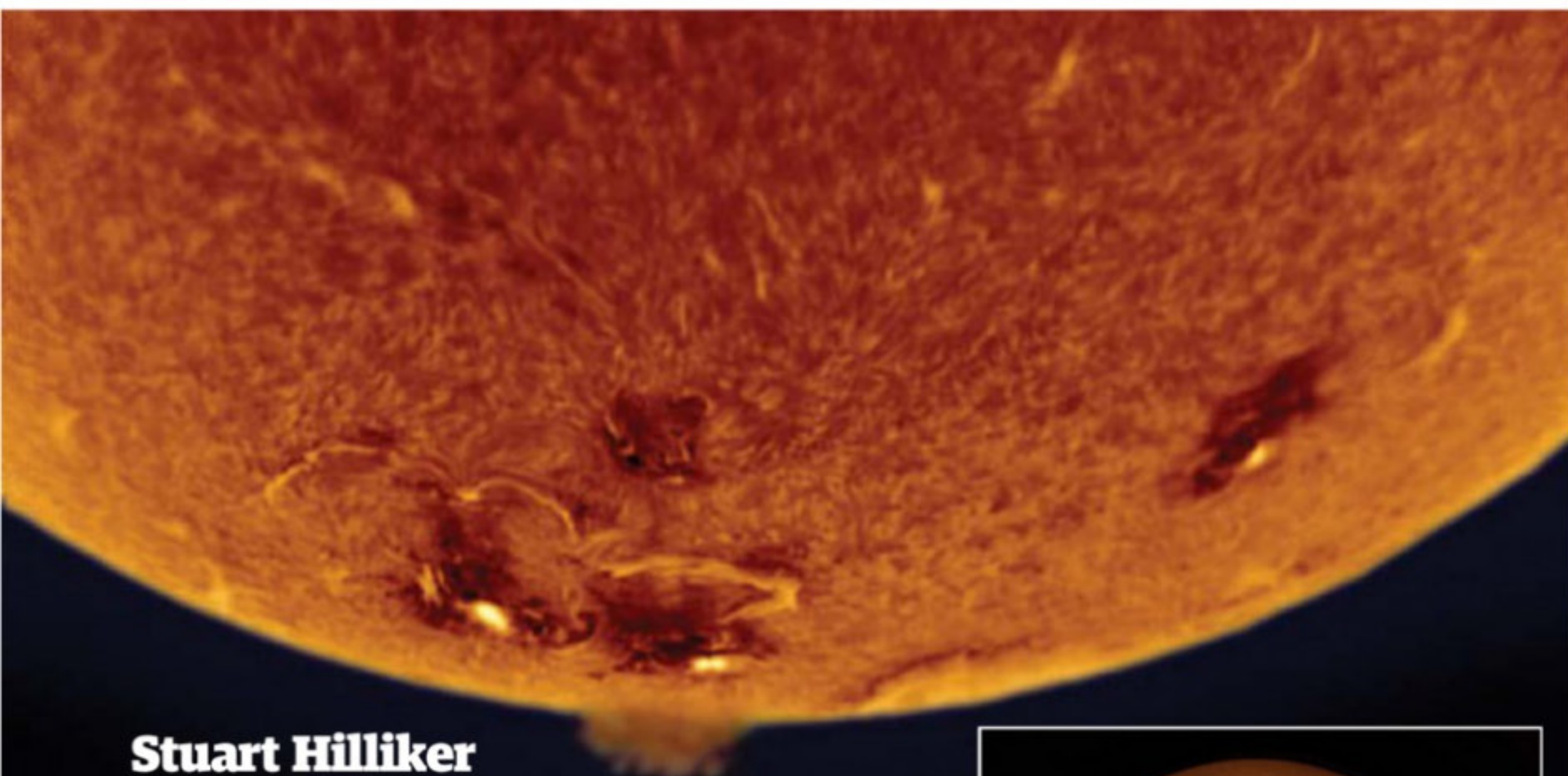
The Milky Way over
Lake Anasagunticook,
Canton, Maine

STARGAZER Me & my telescope



The Pacman nebula (NGC 281)

The Rosette nebula (NGC 2237)



Stuart Hilliker



West Sussex, UK

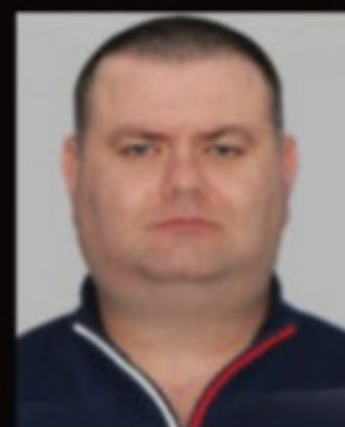
Telescope: Coronado PST

"A few months ago I was planning to upgrade to a larger solar scope but instead purchased a ZWO ASI120MM camera..."

"I used a TeleVue 2.5X Powermate with a Neodymium filter and a Sky-Watcher EQ6 mount. SharpCap was used as the capture software and AutoStakkert! 2 was used to stack the files. I then used RegiStax Wavelet sharpening as the first stage of processing. All other adjustments were made in Photoshop."



Derek Rigby



Brecon, UK

Telescope: Sky-Watcher Skyhawk 1145P

"Taken from my home in Brecon, Wales, this is the very first astro image that I have ever taken. To capture the Moon, I used a Nikon D40 camera mounted to my Sky-Watcher Skyhawk 1145P telescope."

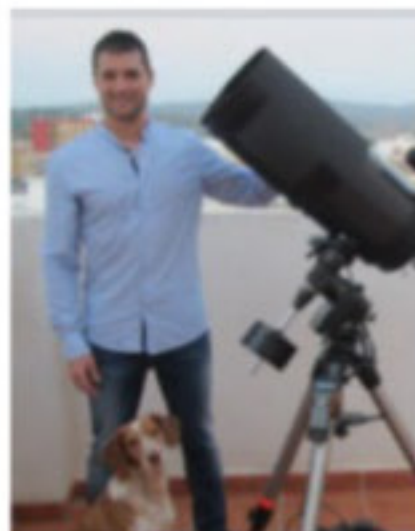


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Stargazing stories

Email the story of how you got into astronomy to **photos@spaceanswers.com** for a chance to feature in **All About Space**

Juan Pablo Revert



Location: Valencia, Spain

Twitter: @Astro_JuPiTeR

Info: Astronomer for 20 years

Current rig

Telescope: Celestron C9.25 SGT XLT f/10

Mount: CG-5 without autoguider

Other: SBIG ST-402ME camera, Focal reducer f/6.3, Barlow Celestron Ultima SV 2X APO, ToUcam PRO II SCI camera.

"When I was 8 years old, I asked my parents if I could have a telescope, but when I was over ten years old I was given my first telescope, which was a 60mm refractor. Ever since I was given my first telescope, my hobby in astronomy has played a massive part in my life.

"For some time, I studied the night sky while juggling work. In 2005, I regretfully had to leave my hobby completely. However, it wasn't for long and I was soon back in the thick of observing and photographing the night sky and the objects within it. Now that I am giving my hobby my

full attention, I am back at it with enthusiasm and excitement.

"In terms of telescopes, I have owned a 10" Dobsonian and a Meade ETX 90. My current telescope is my Celestron C9.25 Schmidt-Cassegrain. By investing many hours into my hobby, I get fantastic results I'm very proud of.

"Sadly, there's a lot of light pollution at the location that I carry out most of my observations. To reduce this... I use a pollution filter, an Astronomik CLS extendable tube and a highly sensitive camera. I obtain detailed shots by using shorter exposure times." ■

"By investing many hours into my hobby, I get fantastic results I'm very proud of"

Juan's top three tips

1. Start off simple

The best way to get to grips with the techniques needed for astrophotography is to start off with the basics.

2. Be patient

Astrophotography takes a long time to master, so just be patient, have faith and you'll soon see your results improving.

3. If in doubt, ask!

If you're having difficulty, then don't be afraid to ask more-experienced astronomers for help and some words of advice.



"The Crescent emission nebula (NGC 6888) in the constellation of Cygnus"

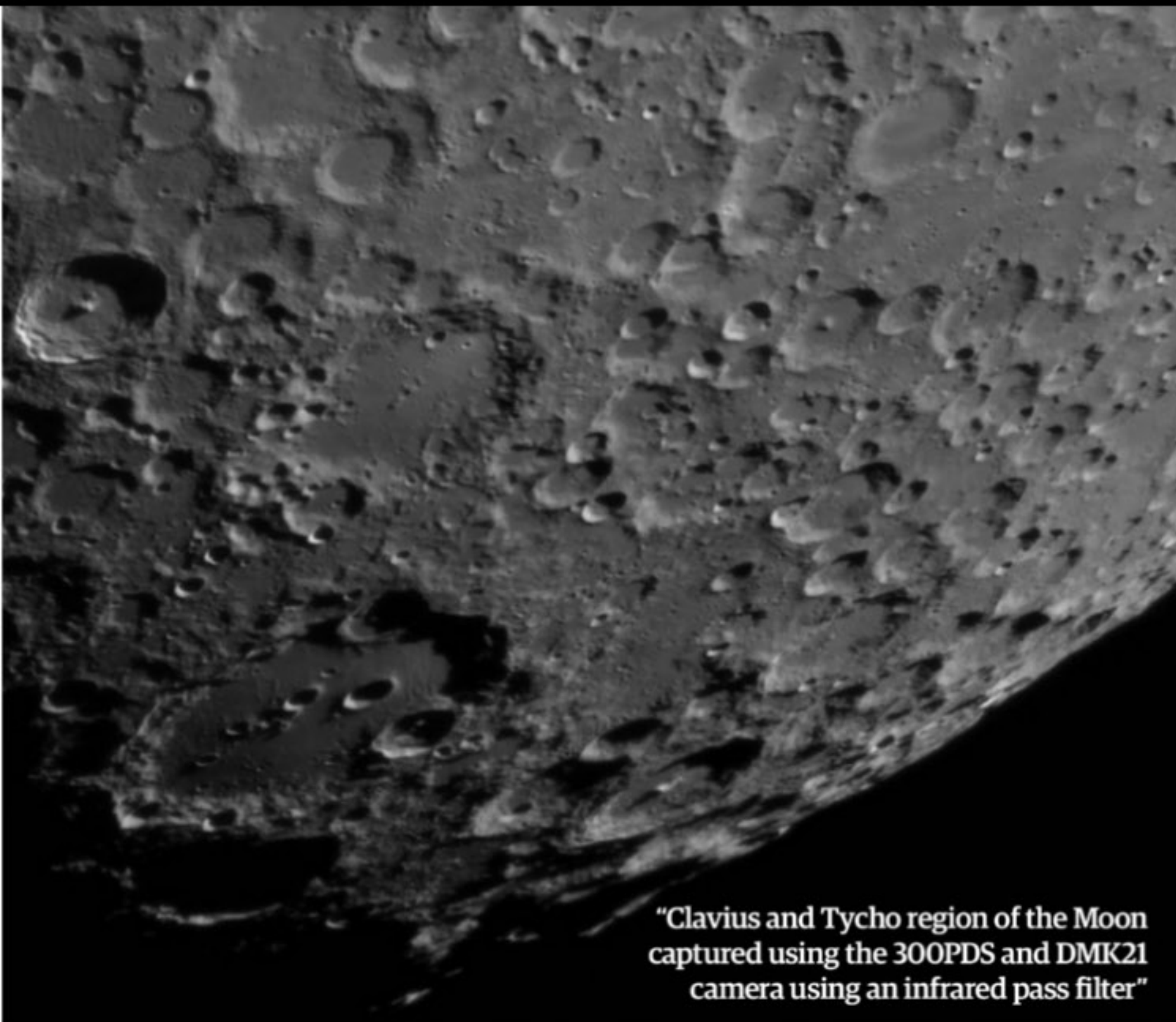


"The Pillars of Creation in the Eagle nebula (M16)"



"The Dumbbell nebula (M27). I used RGB filters to play up the colours"

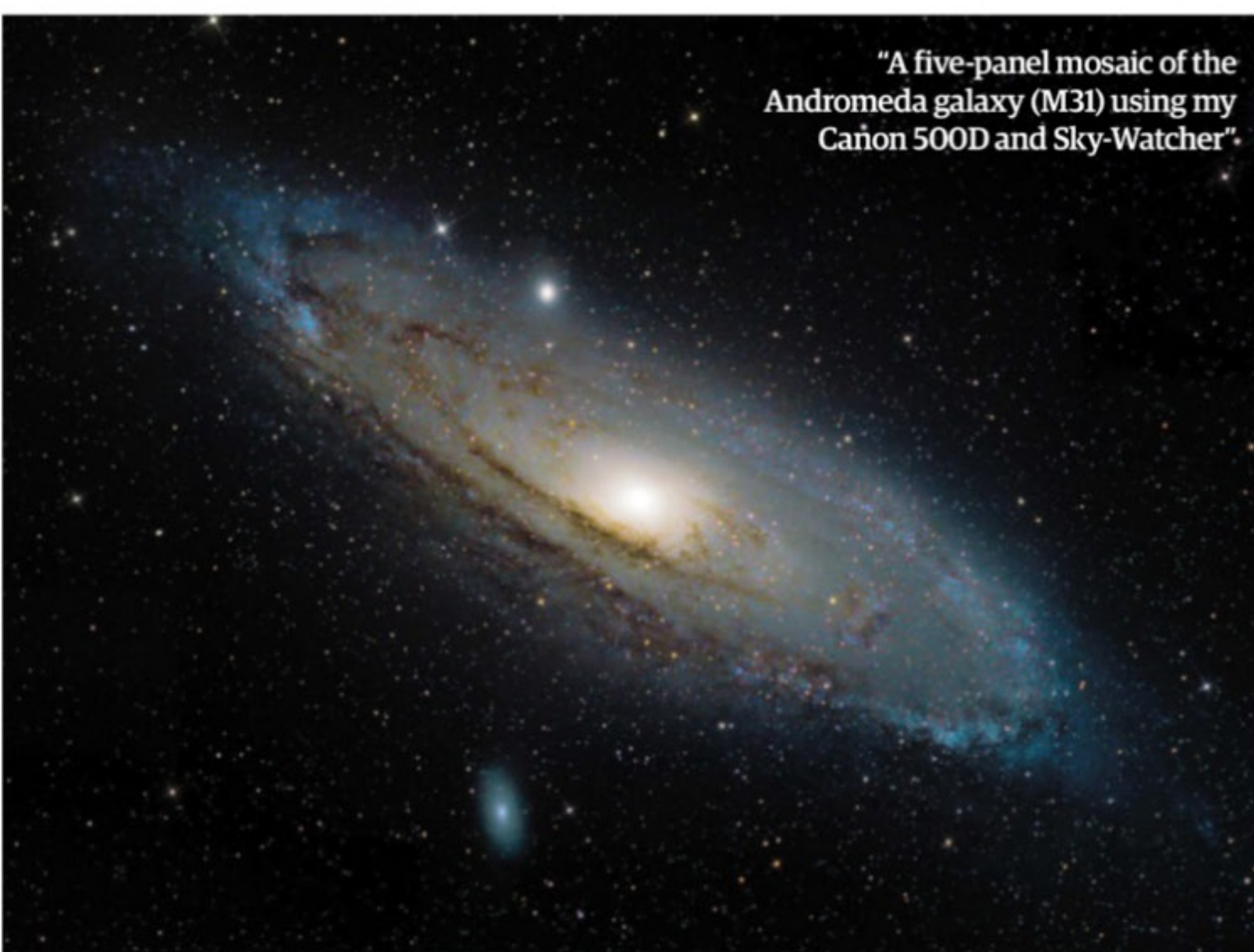
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"Clavius and Tycho region of the Moon captured using the 300PDS and DMK21 camera using an infrared pass filter"



"The Orion nebula (M42) using a Canon 500D and Sky-Watcher 120ED"



"A five-panel mosaic of the Andromeda galaxy (M31) using my Canon 500D and Sky-Watcher"

Mike Greenham



Location: Midlands, UK

Twitter: @AstroMike247

Info: Astronomer for 5 years

Current rig

telescope: Sky-Watcher 120ED and Sky-Watcher 300PDS

Mount: NEQ6

Other: Canon DSLR, DMK21AU618, QHY IMG132E

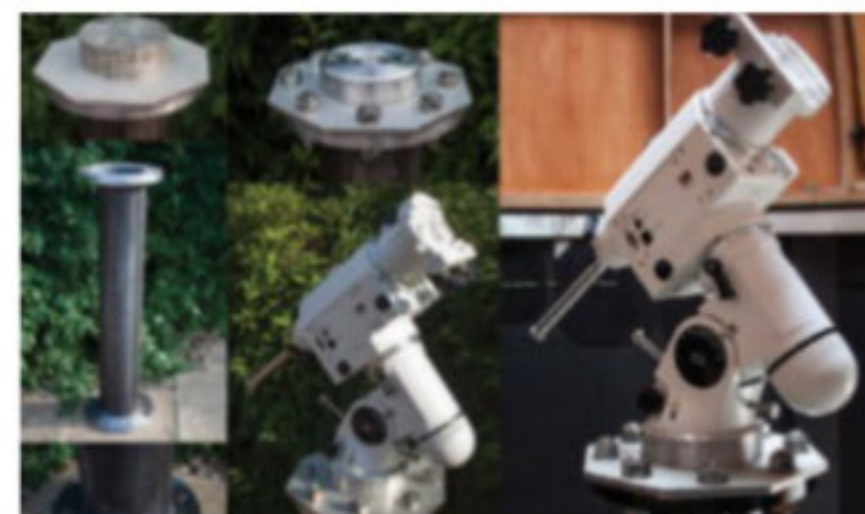
"I've always had an interest in science and space but it wasn't until my daughter asked for a telescope for her birthday that I became interested in astronomy. After buying her a small 3" reflector on a wobbly mount, we soon became frustrated and I began searching eBay for a larger one. I found a 6" reflector on an EQ3 mount locally and brought it home, seat-belted onto the back seat of my car...

"Initially we only used it for observing, but one day while viewing the Moon I placed my phone's camera against the eyepiece in order to show others what I could see. That was it - I was instantly hooked on astrophotography. The passion, along with the cost, grew as I strived to take better and better images and from then on could be found in the garden,

even on a cloudy night, in the hope the clouds would part long enough for me to get a couple of pictures.

"As my setup got larger, heavier and more time-consuming to set up, I began looking at observatories. With the wife already frowning on astronomical purchases, I knew there was no way I was sneaking one of them into the garden so decided the only way was to build my own.

After lots of reading and looking at telescopes built by others online, I decided on the design and built my dome. Having your setup permanently mounted is great as you can be out imaging within minutes, however it has made me too lazy to strip it all down and travel to a dark site. I do all of my imaging from my back garden on the outskirts of a small town." ■



Mike's top three tips

1. Watch elevation

Keep an eye on the Moon's elevation and get out there when it's at its highest. This is when you're looking through less atmosphere, so views are improved.

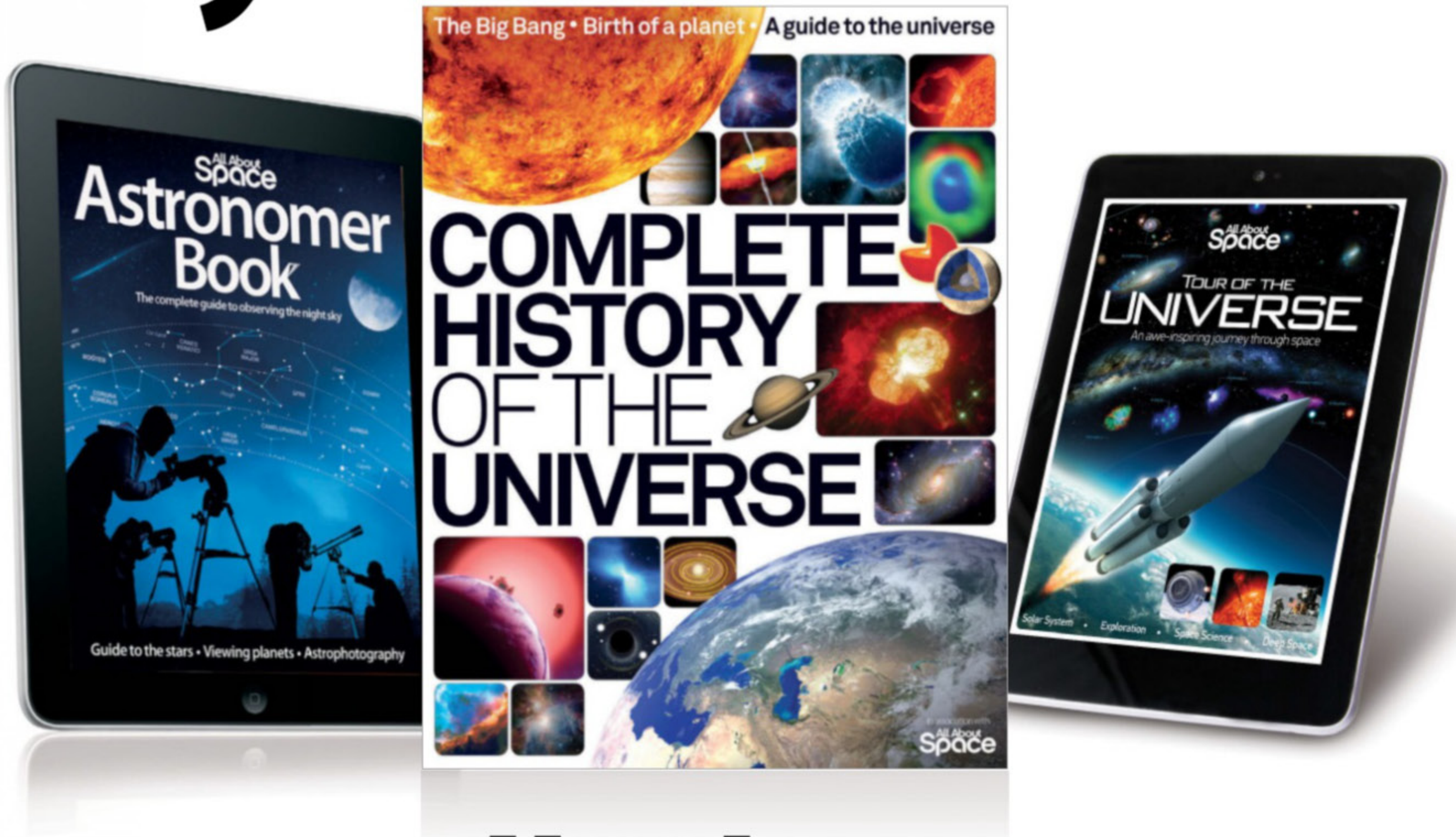
2. Use an infrared pass filter

Light waves in this range are less affected by distortions in the atmosphere, so your images will usually come out sharper.

3. Create mosaics

Ensure that you overlap each panel - I've lost count how many times I've spent hours capturing lots of data only to discover I missed a huge chunk.

The universe in your hands



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STARGAZER

Orion StarBlast 6i IntelliScope

This beginner-to-intermediate desktop Dob has a light-gathering ability to be proud of

The StarBlast collects a good amount of light. While the views of planetary targets were small, they were also very sharp



■ **EZ Finder**
This adjustable red dot sighting device was very useful when aiming the StarBlast at objects in the night sky.

■ **10mm and 25mm Plössl eyepieces**
The eyepieces supplied gave magnifications of 75x and 30x and provided fair eye relief. They combine with the tube's optics for clear views.

■ **IntelliScope Object Locator**
The StarBlast was able to find out where it was in the universe, but required more guidance than usual GoTo telescopes.

"We were treated to sharp views of the outer planet's rings"

Telescope advice

Cost: £449 / \$459.99

From: www.widescreen-centre.co.uk

Type: Dobsonian / reflector

Aperture: 150mm (6")

Focal length: 750mm (29.5")

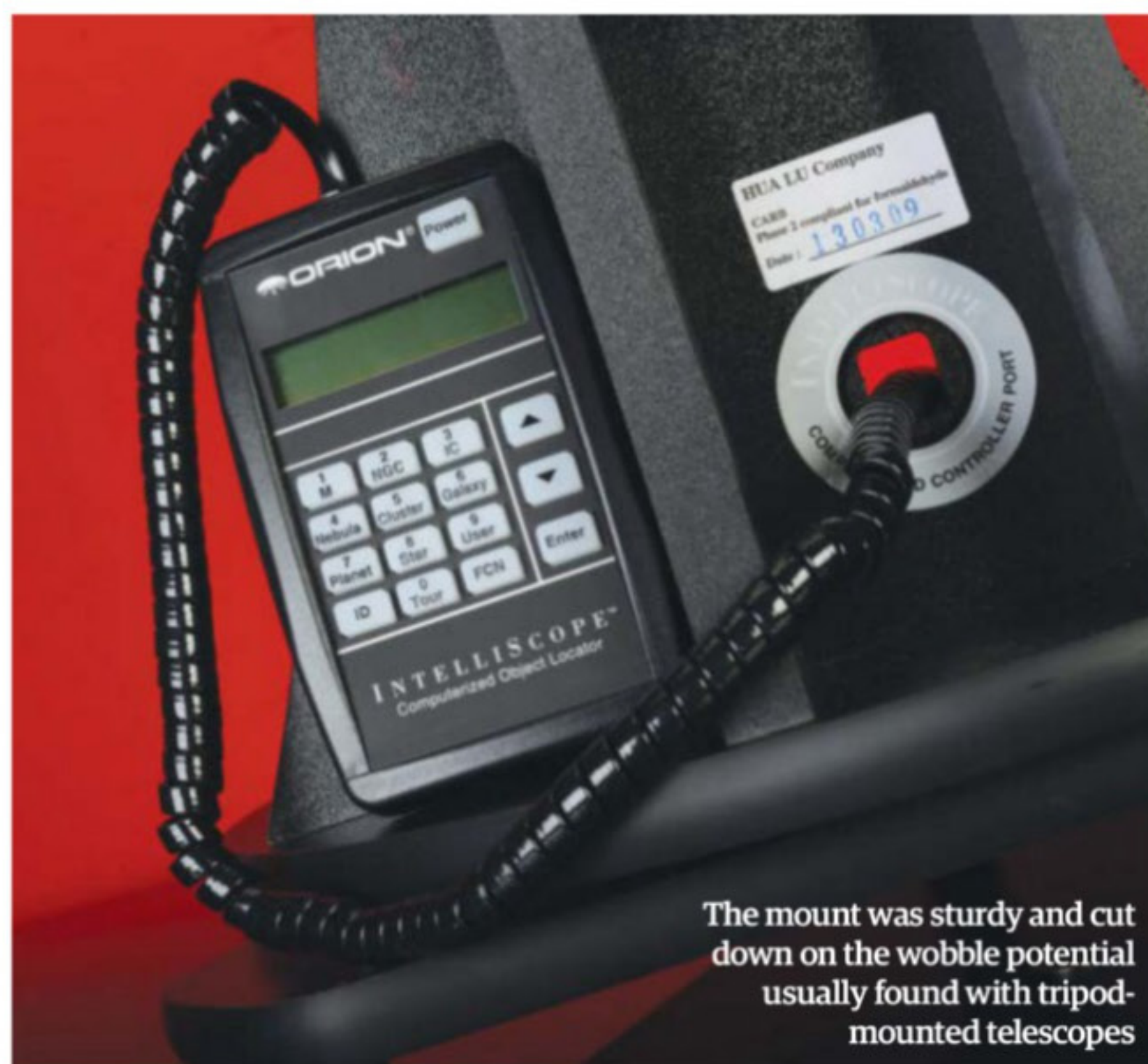
The StarBlast's optical design far surpasses what we expected for the price. Visible details on the Moon were impressive and we were able to view the rings of Saturn under very good observing conditions using the supplied 10mm Plössl eyepiece, which provides 75x magnification.

While we were able to find night-sky objects fairly easily using the IntelliScope Computerised Object Locator, it's worth noting that this electronic device tells you where to move the telescope, rather than actually carry the action out of its own

accord. Instead, you have to manually find one of the 14,000 targets in the IntelliScope's library, which is arduous compared with other GoTo scopes that move the instrument for you.

Turning the StarBlast to Saturn for planetary viewing, we were treated to sharp views of the outer planet's rings. In general, we were very impressed with the views through this telescope and - combined with the Starry Night software and eyepieces - you really are getting your money's worth. With a useful magnification of 300x, there's plenty of opportunity to accessorise this telescope, too.

The general assembly of the telescope, which includes circuit boards to get the IntelliScope Computerised Object Locator up and running, might be a bit too time-consuming for first-time astronomers, despite its ability in taking the mystery out of the night sky. ■



The mount was sturdy and cut down on the wobble potential usually found with tripod-mounted telescopes

Astronomy kit reviews

Must-have products for budding and experienced astronomers alike

1 CCD Celestron NexImage Solar System Imager

Cost: £129 / \$149.95

From: www.dhinds.co.uk

Many find astrophotography daunting, but the NexImage Solar System Imager is both easy to set up and use. It also comes with a starter CD featuring easy-to-follow steps.

Accompanying the NexImage package is video-capture software iCap, plus RegiStax for image processing. The 1.25-inch adapter turned out to be a bit on the small side and measured only 1.23 inches, so we had to ensure the camera was fitted properly to the eyepiece holder.

When put to the test, the NexImage provided reasonable colour sensitivity, but it sadly seemed to produce quite a bit of noise and gave some objects a reddish hue. This wasn't noticeable as much for imaging Mars, but it failed to pick out cooler, bluer colourings on the Moon, for instance. Teaming it up with an H-alpha filter, the camera also struggled to reveal the finer details of the Sun. ■

2 Tracker Celestron StarSense AutoAlign

Cost: £339 / \$518.95

From: www.dhinds.co.uk

The Celestron StarSense AutoAlign enables you to get straight down to observing, removing the need to align your telescope and find the best night-sky targets.

Many might feel that this accessory is expensive - a luxury item for the astronomer who has everything. However, having automatically aligned our telescope less than five minutes from the push of a button, making our tour of the night sky more enjoyable, we were able to appreciate the StarSense AutoAlign's incredible usefulness - especially when it comes to the novice astronomer.

Once set up, we were amazed at how accurate AutoAlign was and as an added bonus, the device even fared well in hazy twilight skies of summer. If you want to get straight down to observing, rather than fiddling about trying to find your chosen target, then this is the kit for you. ■

3 Barlow lens Celestron X-Cel LX 3x Barlow Lens

Cost: £95 / \$122.95

From: www.dhinds.co.uk

When it comes to clarity, this Barlow lens didn't disappoint as we made the lunar surface our first target. In fact, the view was so good, we feel this lens should be on the wish list for every amateur astronomer - especially those who are always looking to increase their viewing options.

Turning our attention to the planets, we targeted Mars and were impressed with the clarity and colour of the planet's surface, playing up our neighbour's features beautifully.

The single-screw brass connection works wonderfully and makes changing up eyepieces a breeze, with focusing also easy. If you're sitting on the fence about getting a Barlow from this range, we'd definitely suggest taking the plunge. If you're unsure of buying one that packs such a punch in magnification, we can recommend the lower 2x Barlow that works with similar sophistication. ■

4 Eyepieces Celestron X-Cel LX series

Cost: £89 each / \$112.95 each

From: www.dhinds.co.uk

We were mightily impressed with this series of eyepieces from telescope giant Celestron, as the Plössl lenses that came with one of our in-house telescopes were cast aside in favour of the X-Cel LX series. Our tour of the night sky became much more enhanced and we noticed a giant leap in quality thanks to the six-element, fully multi-coated design and a generous 60-degree field of view.

The eye relief of the twist-up eyecups is also very good and we used them to tour the night sky for some time. With ease, we picked out detail in several targets including the Whirlpool galaxy (M51), the darker regions of Mars' surface and double stars, which were split cleanly under very good observing conditions.

The caps were snug and a bit of a struggle to take off, but this is a minor flaw that doesn't diminish the quality of this excellent X-Cel LX series. ■



Ham is awarded an apple following his successful recovery from the Atlantic Ocean

Ham the chimpanzee

As the first primate in space, Ham paved the way for human exploration

Born during the summer of 1957, this chimpanzee's life would make history in America's space program. It all began with his capture: Ham was taken away from his home in Cameroon in the west of Central Africa, before being sent to a farm in Miami, Florida. He was held in captivity and was only later purchased by the United States Air Force.

Taken from his home known as Rare Bird Farm, the two-year-old chimpanzee was sent to Holloman Air Force Base, New Mexico in 1959. Here he would meet 40 of his own kind and it wasn't long until he would be pitted against each of them, taking part in a series of training tests that would see him leave the Earth's atmosphere into space. Known simply as No. 65, the chimpanzee took part in evaluation after evaluation until he was one of six potential primates to fly.

Under the supervision of Joseph Brady, a neuroscientist at the Air Force Base's Aero Medical Field Laboratory, No. 65 did well on his tasks where he responded to electric lights and sounds. His reaction speeds were

impeccable compared with the others he trained with, as he quickly pushed levers within five seconds of seeing a flashing blue light. He was a fast learner and quickly figured out that a correct response to his training would earn him a banana treat.

Soon he was ready to board suborbital flight MR-2 as part of Project Mercury on the very last day of January 1961. NASA was a newly formed space agency at this point in history and the mission would be the United States' first step in a major project to eventually put a human astronaut in orbit around Earth.

Launched from Cape Canaveral, Florida, scientists on the ground monitored his health and watched as the astrochimp completed his tasks – it was soon revealed that he achieved them a fraction of a second slower than he had done so in pre-flight training. However, soon into the flight, ground control had cause to worry: the MR-2 capsule began to suffer loss of pressure and they waited with bated breath for the worst to happen. Amazingly though, No. 65 avoided

any harm thanks to his pressurised spacesuit and continued to prove that it was possible to achieve his assigned tasks in space.

When it was time to come back down to the Earth, the chimpanzee's return wasn't a soft one by any stretch of the imagination. The capsule hurtled through our planet's atmosphere, splashing in the Atlantic Ocean, and was later recovered by a rescue ship – but would there be a life to rescue? Opening the capsule's hatch, his rescuers found the chimp had survived his 16 minutes and 39 seconds to and from space with nothing more than a bruised nose.

The fledgling NASA no longer had cause to worry about the public's reaction to naming the chimp prior to this unpredictable mission, so his designated number was taken away and he was given a name. The chimpanzee became known as Ham – an acronym for the laboratory that prepared him for his mission, the Holloman Aerospace Medical Center.

Ham lived out the next 17 years of his life in the National Zoo in Washington, D.C. before moving to the North Carolina Zoo. Following Ham's mission, in May 1961, astronaut Alan Shepard was launched into space aboard Freedom 7. This was the United States' first human spaceflight under Project Mercury, which owes its great success to the results returned by Ham – an animal astronaut who has earned his place on the International Space Hall of Fame. ●

All About Space

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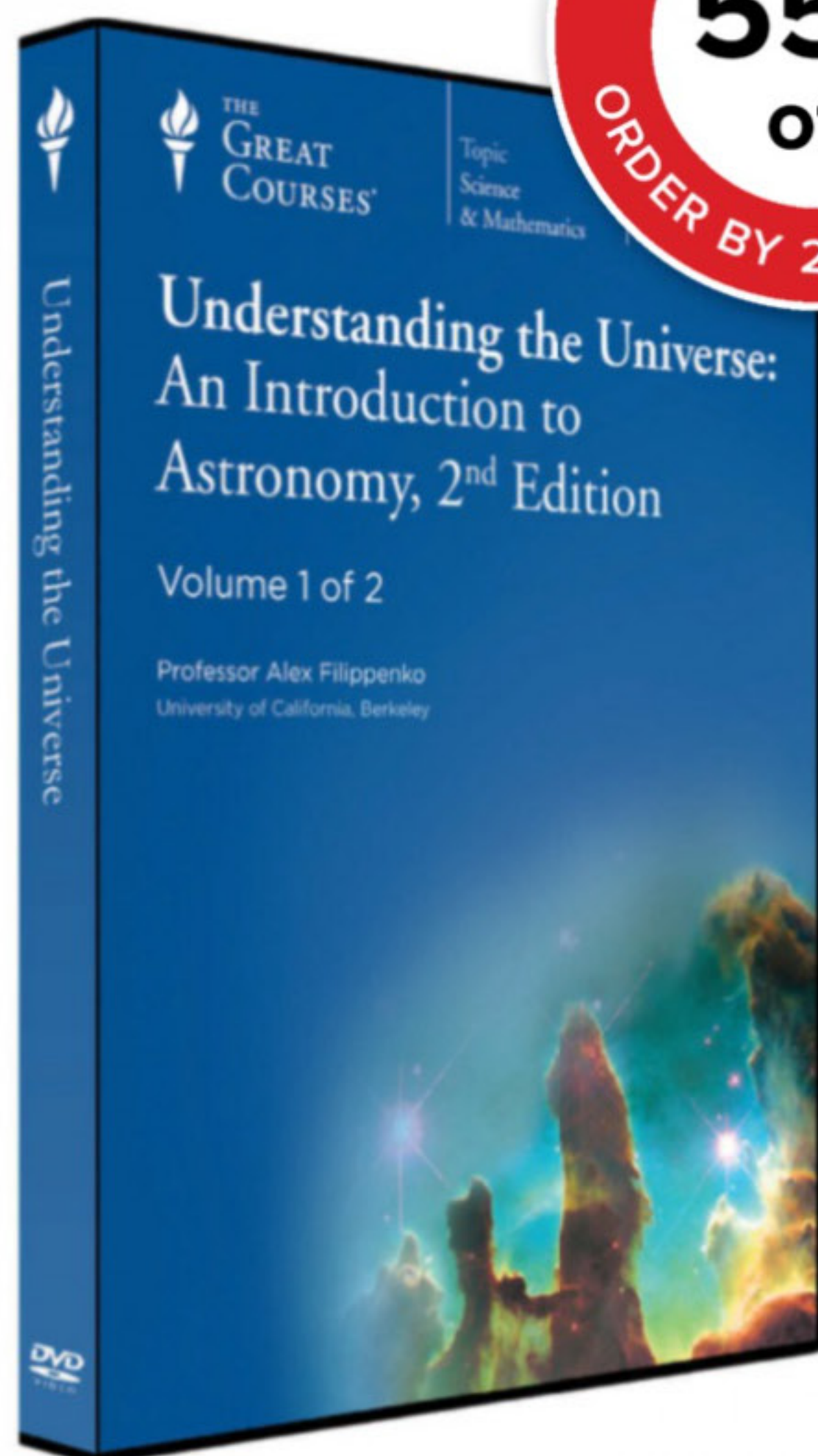
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